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The microbial content of the dried anaphage was as low or lower than that found in commercial feeds. The anaphage can be fed to chickens up to 12.5% of the ration, but it has a very low metabolizable energy content. Up to 75% of the excreta moisture can be removed by use of the ventilation air. Little odor could be detected coming from the system. The cost of drying fresh (75% to 80% moisture) caged layer excreta may be high; however, by utilizing optimum in-house drying techniques, this cost can be reduced by 80%, thus making dehydration a viable pollution control alternative for the commercial poultry production industry.

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POULTRY EXCRETA DEHYDRATION AND UTILIZATION: SYSTEM DEVELOPMENT AND DEMONSTRATION

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FOREWORD

Environmental protection efforts are increasingly directed towards preventing adverse health and ecological effects associated with specific compounds of natural or human origin. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools for assessing and controlling adverse environmental effects of non-irrigated agriculture and of silviculture.

As poultry farming evolves into large-scale production units, commercial poultrymen are faced with increasing problems of excreta disposal under environmentally acceptable conditions. The project described here transforms poultry waste into a product with high nutritive value for livestock and poultry and, at the same time, provides improved odor abatement and pollution control.

David W. Duttweiler
Director
Environmental Research Laboratory
Athens, Georgia

ABSTRACT

A manure handling and drying system involving caged layers with daily manure collection, air drying, and dehydration in a flash-type dryer has been studied. Objectives of the study were to: (1) develop a complete manure handling system to maximize pollution control; (2) determine optimum operating conditions; (3) minimize energy required of the system; (4) determine certain microbial and nutritional qualities of the dried product; (5) be adaptable to commercial poultry operations; and (6) determine the economics of the system.

The system was developed in a commercial-type poultry building with four rows of wire, triple-deck cages. The droppings from the upper two cage rows were hand scraped daily to the pit below the bottom cage row. A cable-blade scraper removed these droppings to a conveyor belt in a drying tunnel. The droppings remained on the belt approximately 24 hours. At the end of the 24-hour period, the droppings were conveyed into a flash-type dryer.

The microbial content of the dried anaphage was as low or lower than that found in commercial feeds. The anaphage can be fed to chickens up to 12.5% of the ration, but it has a very low metabolizable energy content. Up to 75% of the excreta moisture can be removed by use of the ventilation air. Little odor could be detected coming from the system. The cost of drying fresh (75% to 80% moisture) caged layer excreta may be high; however, by utilizing optimum in-house drying techniques, this cost can be reduced by 80%, thus making dehydration a viable pollution control alternative for the commercial poultry production industry.

This report was submitted in fulfillment of Contract No. S802182-01-2 by Michigan State University under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period March 1, 1973, to February 28, 1975, and work was completed as of Fall 1975.

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LIST OF ABBREVIATIONS

cm -- centimeter
DPW -- dried poultry waste
F -- Fahrenheit
ft. -- feet
g, gm -- gram
hp -- horsepower
in. -- inch
kg -- kilogram
km -- kilometer
lb. -- pound
m -- meter
μg -- micrograms
min. -- minute
ml -- millimeter
P -- phosphorus
sec. -- second

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We also wish to acknowledge the engineering, planning and fabrication of the fans into the experimental house by Aerovent Fan & Equipment, Inc., Lansing, Michigan and the advice and counsel of the Consumers Power Company of Jackson, Michigan.

Thanks are also due to Dr. L. R. Champion, Professor in the Department of Poultry Science, for supervising and editing all papers included in this report.

SECTION 1

INTRODUCTION: PROJECT NEEDS AND OBJECTIVES

GENERAL BACKGROUND

The disposal of poultry waste has become a major, practical and serious problem facing the commercial poultryman today. This problem has been brought into sharp focus recently due to the increased concentration of poultry in small areas under single management, the decline in public acceptance of the use of animal excreta as a fertilizer (land spreading), and legislation to limit or prevent environmental contamination, including dust, odors, water pollution, rodents and flies.

Historically, the only practical and feasible method of disposal for poultry excreta has been field spreading on available land. Alternative methods of excreta disposal, in the main, have been based on handling and treating the waste in liquid form. Poultry excreta, to be handled as a liquid, must then be diluted, which causes an increased volume that can be a significant disadvantage upon subsequent handling. Poultry excreta, a semi-solid, contains 80% moisture. Therefore, it would seem logical to develop a poultry waste management system for pollution control that would take advantage of the excreta as it comes from the bird.

SCOPE AND PURPOSE

To better manage our resources, a large percentage of the poultry excreta available should be utilized in recycling systems, thus markedly reducing the burden on land spreading and water to hold and treat these wastes. Not only would recycling improve the environment and conserve scarce resources, it could also effectively increase the production efficiency in the animal industries.

The overall goal of this project was to develop and demonstrate the handling, dehydration, and utilization of poultry excreta. The management of poultry excreta in a closed ecological system was envisioned; the excreta from poultry would be transformed into a product that had high nutritive value for livestock and/or poultry. Thus, the concept was to develop a waste reclamation system that incorporated odor abatement and pollution control with a maximizing of energy conservation. Even in this closed system, flexibility was needed for emergency or contingency situations. This system included a high temperature dryer to transform the excreta to a stable product for use either as a feed ingredient or fertilizer. In addition, the system had the possibility of field spreading in the conventional method.

The specific objectives of this project were:

1. To develop and demonstrate a complete pollution free poultry excreta handling system.
2. To determine the optimum dehydration conditions for the pollution free multiphase drying system.
3. To minimize energy consumption and odor produced.
4. To evaluate the dehydrated end-product for nutritive value.
5. To determine the economicsof the complete excreta handling and dehydration system.

This report will summarize the results obtained in the investigation carried out to develop and demonstrate the objectives as outlined above.

FACILITIES FOR INVESTIGATIONS

The facilities utilized to conduct these investigations consisted of the Poultry Science Research and Teaching Center, the Animal Waste Management Laboratory and laboratory facilities within the Poultry Science and Agricultural Engineering Departments at Michigan State University, East Lansing, Michigan.

The Poultry Science Research and Teaching Center, located on Jolly Road, East Lansing, Michigan, was the site of the demonstration phase of this project. The building utilized was cross ventilated, had a concrete floor and was a clear-span cage laying facility that consisted of 385.4 square meters of floor space. The building also contained appropriate monitoring equipment, bird housing facilities, an excreta dehydrator and afterburner, a PVC belt (for excreta drying) and a high rate filter chamber.

The laboratory facilities used included appropriate equipment to conduct nutritional, biological, bacteriological, physical, chemical and computer simulation studies.

HOUSE DESIGN AND OPERATION

Materials and Methods

The testing period considered in this project included data collected from July, 1973, to February, 1975.

House

One of the existing buildings in the Poultry Science Research and Teaching Center (PSR&TC) on the M.S.U. campus was converted into a demonstration unit for this project. A clear-span, pole and truss building was remodeled from an exisiting poultry house to accommodate this project. Figure 1 illustrates the floor plan and sectional view of this modified house. The original house was 12.19 m (40 ft.) wide and 45.72 m (150 ft.) long, with a 3.66 m x 12.19 m (12 ft. x 40 ft.) feed and viewing room. Only 36.43 m (90 ft.) of the existing building was utilized for this experiment. The remaining 15.20 m (50 ft.) was used for a storage and work area for the project but was not taken into account in any of the calculated data.

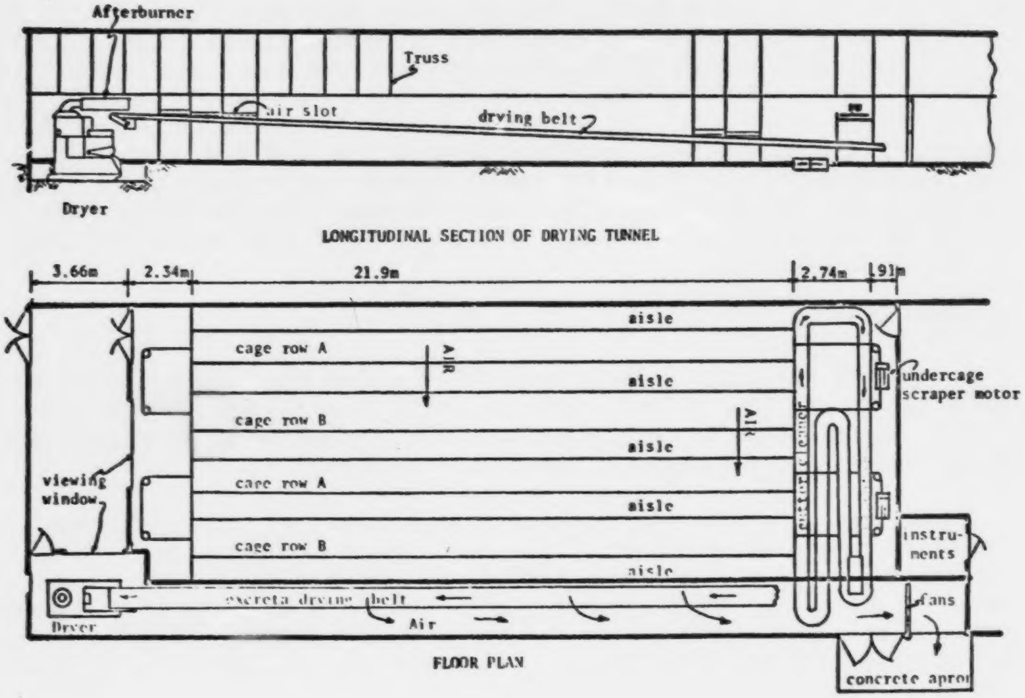

Figure 1. Floor plan and section view of the modified poultry house. A heat exchanger consisting of five parallel runs of 10-inch (25 cm) stovepipe carries exhaust gases from the afterburner over the drying belt toward the fans. The heat exchanger is not shown in this figure.

The ceiling and sidewalls contained 15.24 cm and 10.16 cm of fiberglas insulation, respectively. The inside ceiling and sidewalls were 0.952 cm exterior plywood. The roof and outside walls were .61 mm aluminum.

Cages

Four rows of triple-deck, stacked wire cages 21.95 m (72 ft.) long (Figures 2 & 3), were used to house the birds. One-half of the cages were 30.48 cm x 40.64 cm (12 in. x 16 in.) and the other half were 40.64 cm x 30.48 cm (16 in. x 12 in.), thus providing a variable number of lineal inches of watering and feeding space per bird. One-half of each type cage contained 4 birds per cage the other half contained 3 birds per cage. The top 2 rows were separated by a dropping board which had to be scraped daily to the pit below the bottom cage row (Figures 4 & 5). A commercial-type, cable-blade scraper (Figure 6) removed all droppings daily to a cross-conveyor (dairy barn gutter cleaner) to the far end of the house. The cross-conveyor elevated the excreta (Figures 7 & 8) to the end of a continuous synthetic (PVC) 76.2 cm (30 in.) wide belt in the drying tunnel.

Watering Device

The original waterer was a commercial v-type continuous plastic trough, which sagged and thus allowed water to spill into the manure pits and on the floor. A correction was attempted by the installation of a v-type, galvanized trough placed underneath the plastic waterer.

However, even with all the corrections attempted, the system was not satisfactory and was replaced after 6 1/2 months of operation. The new system was a 21.95 m (72 ft.) continuous 10.16 cm ordinary house eaves trough fabricated at the site. The 6 standing water troughs (for ad libitum watering) for each row of cages were connected at one end, allowing the overflow water to be funneled into the floor drain. Water spillage was minimized by the installation of the eaves trough waterer.

Cross-Conveyor

The conveyor at the east end of the cage house connected the 4 drag-type manure scrapers and conveyed the excreta (Figures 6-9) to the belt in the drying tunnel. The Clay barn-type cleaner was recessed in the concrete floor, with an elevator at the end, which lifted the manure from floor level to a level of 2 m (6 ft.). This allowed the manure load to be dropped onto the belt, or onto the front-end loader (Figure 9) of the farm tractor. This escape hatch (door) allowed removal of excreta from the cross-conveyor whenever desired.

Drying Tunnel

A drying tunnel was constructed on the side of the building opposite the air inlet slot (Figure 1). The drying tunnel was 1.87 m (74 in.) wide and 2.43 m (8 ft.) high and ran the entire length of the test building. At one end (Figures 1 & 11), 4 fans were installed while the dryer (OPCCO Model 200) was placed at the opposite end of the tunnel, adjacent to the viewing and

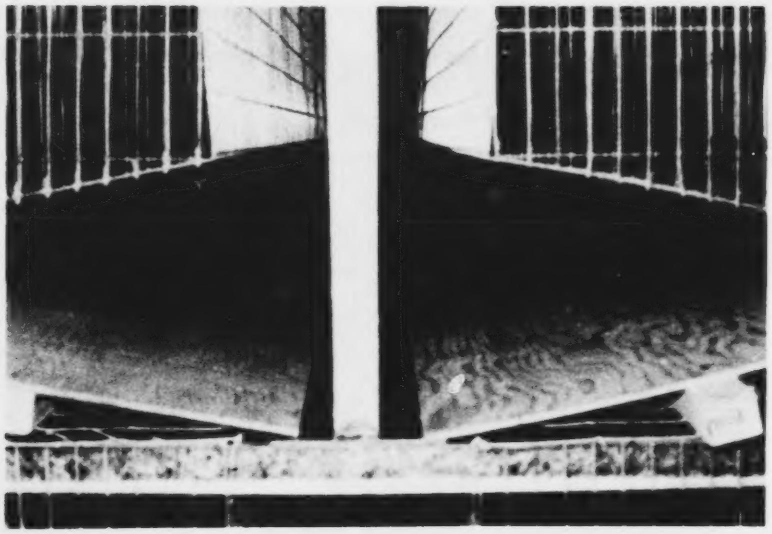

Figure 2. End view showing hanging cages and dropping boards between the second and bottom row.

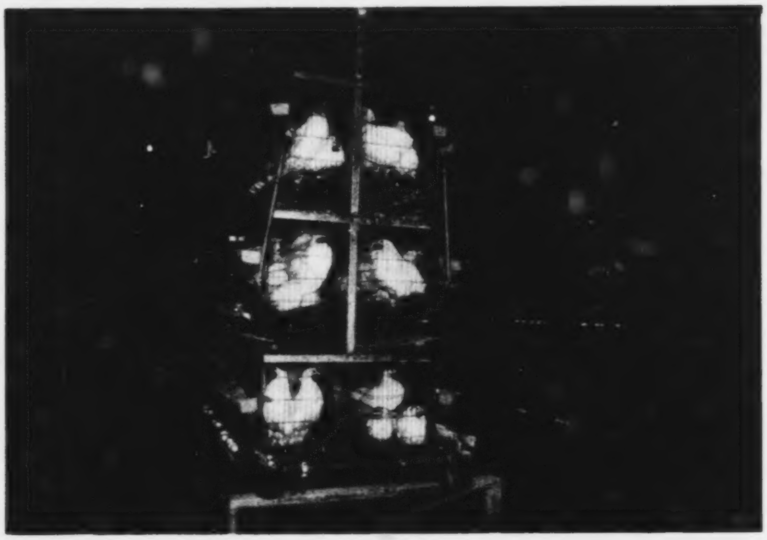

Figure 3. A close-up view of dropping boards between tiers of cages.

Figure 4. An employee scraping dropping boards.

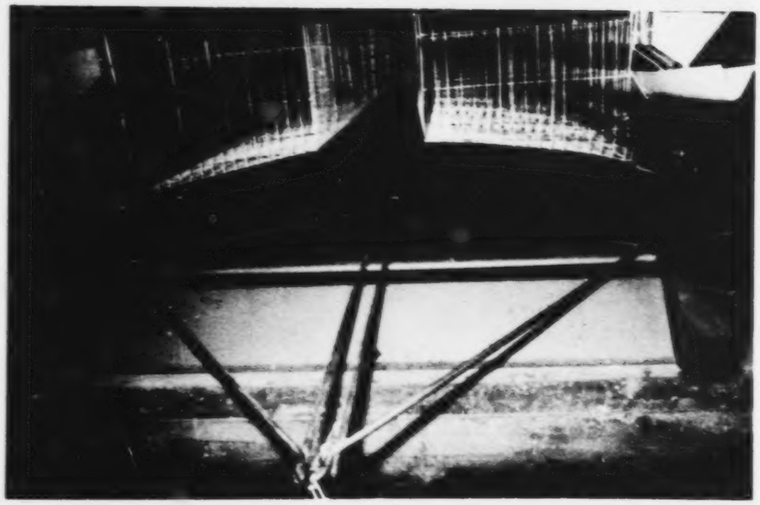

Figure 5. Close-up view of excreta scrapper at the edge of cross conveyor.

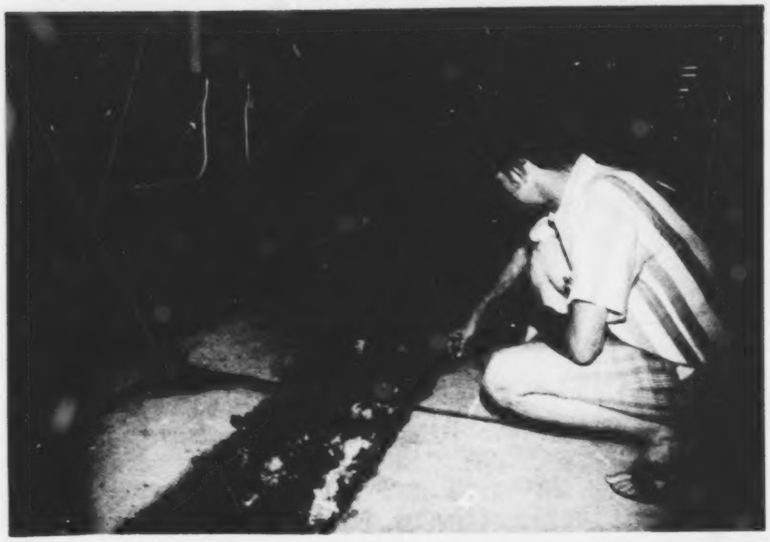

Figure 6. Inspecting the excreta being moved in cross conveyor.

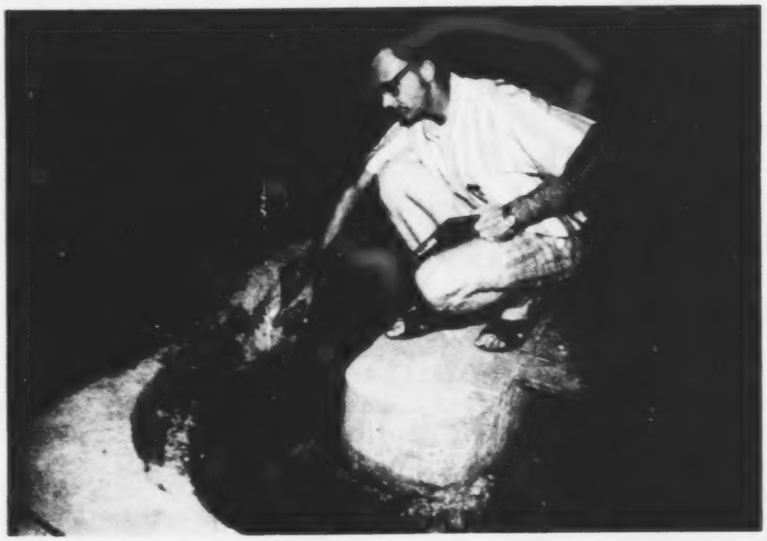

Figure 7. Checking the corner section of the cross conveyor.

feed room. Air movement from the cage house was directed onto the excreta by a series of adjustable baffles on the outlet slot. This warm air movement was to assist in the drying of the fresh excreta.

Conveyor Belt

The continuous PVC conveyor belt was suspended in the drying tunnel from the poultry house trusses. The conveyor was a sliding-tray type, driven at about 3 meters per minute. The excreta was fed into the dryer from the conveyor belt (Figures 8 & 9).

Ventilation Fans

Four, 283.2 cm fans, which operated thermostatically, were located at the one end of the drying tunnel (Figures 1 & 9); one fan was to start operating at 15°C (59°F) and the other 3 fans to start operating at each 2.8°C (5°F) increase in temperature. In addition, adjacent to the 4 large fans, one 6.96 cm (24 in.), (141.6-283.2 cm) fan was located near the loading section of the conveyor. This fan was set to run continuously at a minimum output. A 5.08 cm (2 in.) continuous slot on the side of the building (opposite the fans) was used for winter (October-April) ventilation and a 15.2 cm (6 in.) continuous slot for summer (May-September) ventilation.

Dehydrator

The dehydrator used in this experiment was of the same type described by Surbrook (1969) and was manufactured by the Organic Pollution Control Corporation (OPCCO) of Grand Haven, Michigan. A horizontal-type, oil-fired afterburner (Figure 10) was attached to the dryer and the heat was allowed to be discharged into the drying tunnel. The dryer heat was also exhausted into the tunnel. A heat exchanger that consisted of a plenum chamber and 5 parallel 25 cm (10 in.) diameter stove pipes was used to dissipate the heat and for heat reutilization from both the afterburner and the dryer. The final product, Poultry Anaphage (PA or Dried Poultry Waste, DPW) was bagged at the dryer.

Appropriate monitoring equipment was installed to measure electrical inputs, fuel consumption, air movement, relative humidity and dryer output.

Cage Layer Ration

The typical cage rations (Table 1) and water were provided *ad libitum*. The calculated analysis of the ration was 16.0% protein, 3.54% fat, 2.95% fiber, 3.30% calcium and available phosphorus was 0.48%. The calculated metabolizable energy was 1310 Kcal/lb.

The laying flock was fed a standard cage layer ration for the first 6 1/2 months in the laying house. After that time, one-half of the birds in the trial were fed Diet No. 1 and one-half of the birds were fed Diet No. 2 (Table 1). The diets were formulated to be isocaloric and each diet contained the same level of calcium and phosphorus.

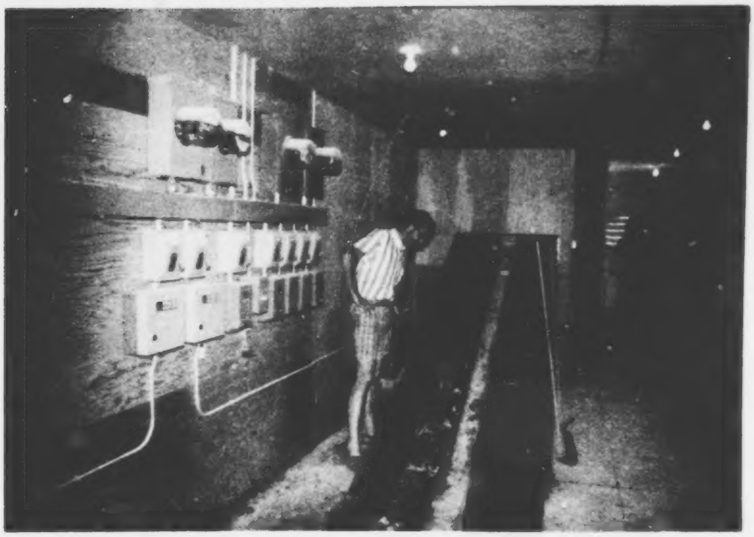

Figure 8. The manure being elevated at end of cross conveyor.

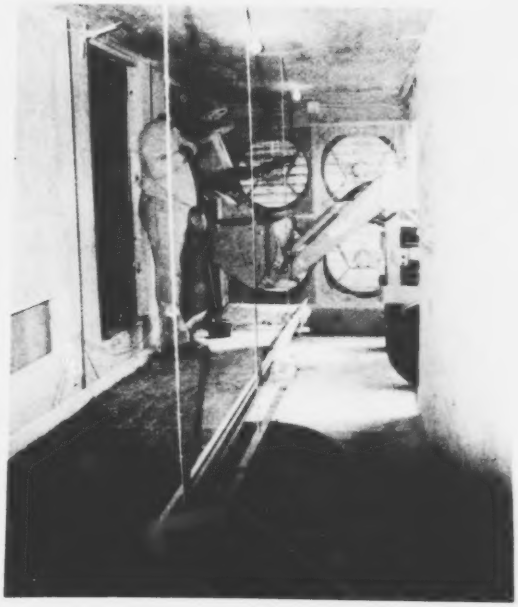

Figure 9. Observing excreta dropping into front-end loader of tractor parked at emergency door.

Figure 10. Checking dryness of excreta on belt. Slotted air vents along dryer belt are in full "open" position.

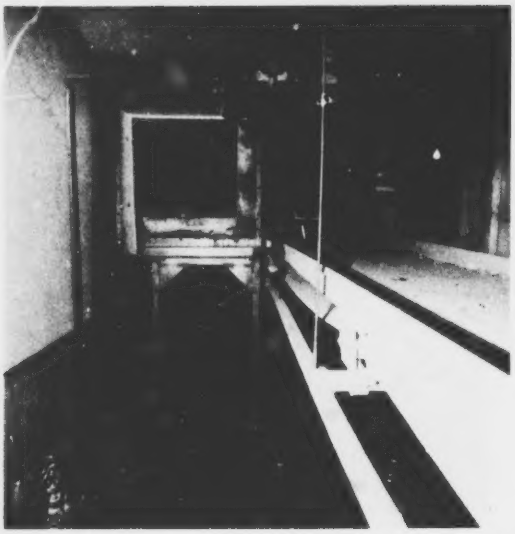

Figure 11. Horizontal afterburner positioned above and left of dehydrator and to right of conveyor belt. Heat from burner is forced along drying chamber.

TABLE 1. COMPOSITION OF EXPERIMENTAL DIETS

Ingredient	Percent of Diet Diet 1	 Diet 2
Corn, ground	68.95	58.95
Soybean meal, 49%	16.50	16.10
Alfalfa, 17%	2.00	2.00
Meat & bone meal, 50%	3.00	3.00
Limestone, ground	7.00	5.70
Dicalcium phosphate	1.25	.025
Methionine, DL	.05	.075
Salt	.25	.25
Fat, A-V	.50	3.40
Layer premix	.50	.50
Anaphage	---	10.00
Total	100.00	100.00
Calculated Analysis:		
Crude protein,	16.00	
Fat, %	3.54	
Fiber, %	2.95	
Calcium, %	3.30	3.30
Phosphorus, % (available)	.48	.48
Metabolizable energy, Cal./lb.	1310	1310

Egg Production

A 14-hour light day was provided for the laying flock (Leghorn type) for the first 6 months and then a 16-hour light day was provided for the remainder of the production period. Twenty-five-watt bulbs were installed in the ceiling fixtures, 3.05 m (10 ft.) on center, down the center of each of 5 rows between the cages. After thirteen, 28-day laying periods of production, the entire flock was force molted (see Flegal, 1975). The post-molt egg production cycle was then continued for 7 1/2 additional 28-day periods. Eggs were gathered once daily and credited to the appropriate treatment group. Both feed and water were supplied ad libitum.

All mortality was recorded and veterinary laboratory examinations were obtained for all mortality during the trial. Diseased tissues or suspected diseased tissues were collected for microscopic diagnosis in the Michigan State University (M.S.U.) Pathology Department, Microbiological Laboratory.

RESULTS

Mortality

Five weeks after the pullets were housed, heavy mortality occurred due to Leukosis infection. Nine months later, avian hepatitis was diagnosed in addition to the continuous Leukosis infection. Eleven months after the pullets were housed, the layers were force-molted and again a heavy mortality occurred.

A monthly mortality record is presented in Table 2. Continuous high mortality during the entire experiment was evident. The mortality rate for the entire project was 26.1%. When the mortality during the 2-month molting period was excluded, the mortality rate was 21.5% (Table 3). The most frequently diagnosed causes of mortality were: 1) lymphoid leukosis, 2) infectious hepatitis, 3) peritonitis, 4) enteritis, and 5) salpingitis.

Necropsy reports for many chickens that died simply listed "no diagnosis" or "emaciation".

Egg Production

Egg production followed a typical curve for the first 75 days after initial housing of the laying flock. After that time, excessive mortality (due to disease) occurred. The excessive mortality limits the validity of subsequent egg production and feed efficiency data. However, neither egg production or mortality was influenced by dietary treatment before or after the molting period.

Of the birds that were fed 10% anaphage in their diet, 702 (49.2% of the total mortality) died during the experimental period (exclusive of molt period). The mortality of the birds that were fed the control diet, zero percent anaphage, amounted to 724 birds, 50.8% of the total mortality during the experimental period.

TABLE 2. MORTALITY OF LAYERS IN THE IN-HOUSE EXCRETA DRYING SYSTEM

Year	Month	No. Birds In The House	No. Birds Added	No. Birds Died
1973	June	4,947		30
	July	4,917		100
	August	4,817		135
	September	4,682		86
	October	4,596		90
	November	4,506	650	80
	December	5,076	350	111
1974	January	5,315		87
	February	5,228		134
	March	5,094		76
	April	5,018		78
	May	4,940		62
	June	4,878	586	158*
	July	5,306		144*
	August	5,162	99	63
	September	5,198		67
	October	5,131		65
	November	5,066		66
	December	5,000		46
1975	January	4,954		50
	February	4,904		

*During the forced molting period

TABLE 3. MORTALITY RATE FOR THE ENTIRE EXPERIMENT

Experimental Period	Total No. Birds Housed	Number Birds Died	Mortality Rate (%)
1973-75	6,632	1,728	26.1
Excluding Molting Months	6,632	1,426	21.5

SECTION 2

CONCLUSIONS

Removal of nearly 75% of the poultry excreta moisture during May-September was possible by using the ventilation air to dry the excreta under the cages and on the belt. About 50% of the poultry excreta moisture can be removed by the same system during the colder months of the year. By the use of a recirculating air system for additional air turbulence over the belt, at least 75% of the excreta moisture can be removed during all seasons. Normal seasonal ventilation rates were used in this house.

Very little odor could be detected at any time as a result of operating this poultry excreta handling system.

By directing all of the ventilation air and dryer exhaust fumes through a vertical water scrubber tower, approximately 75% of the particulate emissions were removed during the operation of the oil-fired dryer both with and without the afterburner operating. The scrubber tower can be operated at a small fraction of the cost of operating the afterburner.

The microbial content of dried poultry anaphage was as low or lower than that found in commercial feeds. Attempts to isolate Salmonella organisms were negative.

The cost of drying fresh (high moisture) caged layer manure is high (about 1 cent for each pound of water removed). However, by replacing the afterburner with the vertical scrubber and employing optimum in-house drying techniques, the cost of producing anaphage can be reduced by 80%; thus, making dehydration economically feasible for the commercial poultry industry.

For successful drying of poultry excreta for pollution control and economy, the spillage of drinking water must be eliminated.

Random stirring of poultry excreta on the plastic belt in the drying tunnel under the experimental test conditions did not improve moisture removal.

The Metabolizable Energy (ME) of poultry anaphage is equivalent to that of certain other feedstuffs such as wheat bran or alfalfa.

Poultry anaphage can be successfully refed to laying hens in amounts not over 12.5% by weight, without any deleterious effects on egg production or mortality.

Public Health Aspects of Refeeding Animal Manures - As of July 1, 1976, the U.S. Public Health Service, Environmental Protection Agency, Food and Drug Administration, or any other federal agency has not given an official sanction to dry, bag, sell and/or feed dried poultry waste and any animal manure to livestock and/or poultry. In fact, a reprinting of paragraph 500.40 of the Federal Register (page 813804, Vol. 40, No. 60) printed on 27 March 1975, reiterated the 1967 stand of the FDA which specifically states that the FDA has not sanctioned and does not sanction the use of poultry litter as a feed or as a component of feed for animals. Six states, California, Mississippi, Georgia, Colorado, Iowa and Oregon have authorized the use of, and have specifications written for the drying and feeding of, animal wastes. Council for Agricultural Science and Technology Report #41, dated February 19, 1975, prepared by a task force under Dr. P. F. Pratt of the University of California, was submitted to the Senate Committee on Agriculture and Forestry (Senator Herman Talmadge, Chairman). This Council for Agricultural Science and Technology Committee pointed out that "Actions are needed that will promote the beneficial use of increased efficiency of the use of sewage sludges and animal manures. As a society with limited resources, we need to stop thinking in negative terms of waste disposal and instead should think in the positive terms of appropriate use".

The USDA released a bulletin in March 1974 entitled "Recycling Poultry Waste as Feed -- Will It Pay?" (Agricultural Economic Report No. 254).

In summary, this Agriculture Economic Report stated that the processing and feeding of dried layer waste (DLW) is economically feasible for large units of caged layers. The highest net returns are attained by the larger operations when DLW is fed at 12.5% of the ration.

The impact of human health aspects of refeeding Dried Poultry Waste was not a part of this EPA project.

SECTION 3

RECOMMENDATIONS

The principle of dehydrating poultry excreta is recommended as a viable manure handling system for pollution control and the production of a feedstuff called anaphage.

When anaphage is to be considered for use as a feed ingredient, it must contain less than 10% moisture and less than 1 million organisms per gram.

Further research should be conducted to produce anaphage utilizing solar energy and making better use of ventilation air to control pollution in a poultry manure handling system.

SECTION 4

INTRODUCTION: IN-HOUSE AND MACHINE DEHYDRATION OF POULTRY EXCRETA

The poultry house design and excreta handling system previously described in this report were designed to maximize excreta dehydration by use of the ventilation air. In addition, a dehydrating machine was employed to lower the excreta moisture so the product could be stored. Therefore, water evaporation could occur from the excreta in four phases:

1. as deposited in the house by ventilation air,
2. as moved from the dropping pits and spread on the belt,
3. on the belt by the ventilation air and waste dryer heat,
4. as run through the heated air dryer.

The purpose of the following experiments was to evaluate the effectiveness of the entire system to remove moisture from the poultry excreta.

MATERIALS AND METHODS

During the first 5 months of this project, 3 samples of excreta from each deck, each side, and each row of cages were collected into tared petri dishes for moisture determinations. This collection was repeated weekly until the following changes were made in December, 1973; then the excreta samples were collected only from the dropping boards (predetermined locations) on the middle decks and half-way down the house. A 4.72 cm square area of excreta was pooled and mixed thoroughly before the sample was taken. Samples were collected directly from the dropping boards in the same area and same manner each time. The handling system was thus operated on a daily basis even though in took approximately 2 days to move the excreta from its initial deposited location onto the belt, through the dryer and out of the house. For experimental and measurement purposes, only Tuesdays and Thursdays were specified as critical data-taking days. After the samples had been collected from the dropping boards, the excreta was moved to the pit at one end of the house before being loaded on the PVC belt in the drying tunnel by the cross-conveyor. Again, 6 predetermined spots on the PVC belt were selected for taking samples. Pooled samples were collected in these same 6 spots each time. The excreta on the belt was stirred in the areas of 4, 5 and 6 at 2-hour intervals during the following 24 hours. Positions 1, 2 and 3 were not stirred (see Figure 1).

Samples were taken from the same areas on the conveyor belt after 24 hours dehydration in the drying tunnel. The 7th sample was taken at the end of the PVC belt when the last portion of excreta reached the dryer. This was to determine whether or not the additional dehydration was taking place while the excreta was moving slowly toward the dryer. It was believed that the heat from the dryer might enhance additional drying of excreta.

Five anaphage samples were collected directly from the dryer in the tightly sealed glass jars at 15 minute intervals. These samples were used for determination of anaphage moisture contents and for microbiological and chemical analyses.

To determine the moisture content of the excreta or anaphage, the A.O.A.C. method with the slight modification was used and briefly described as follows:

Excreta or anaphage was placed into each of 3 tared petri dishes. The samples were weighed, placed into an 100°C oven and weighed again after 24 hours to determine percent moisture. The results of the 3 replicates were averaged to give the final moisture content.

Methods used for odor evaluation were primarily organoleptic for the reason that sophisticated methods (such as gas chromatography) eventually require comparison with odor panel results. Moreover, it was felt that in view of the drastic improvements sought in poultry house odor control, a panel consisting of 3 of the authors of this report, would suffice.

A few measurements were made in the building using a Scentometer in order to lend credibility to our otherwise subjective observations. The Scentometer dilutes the sampled air with another stream of charcoal-filtered air. Charcoal filtration generally removes odors from that second stream. Reported herein are cold weather measurements which are probably higher than warm weather measurements. This is because the ventilation rates are much lower in winter.

In hog buildings, hydrogen sulfide was found to be a good indicator of the general odor level in a building (Avery, Merva and Gerrish, 1975). Even when hydrogen sulfide (H_2S) concentrations are less that the detection threshold of 0.7 parts per million (ppm), H_2S concentration can still be estimated based on general odor level. H_2S does evolve from decomposing poultry manure under certain conditions (Burnett and Dondero, 1969). Consequently, determinations of H_2S concentration give some indication of odor level.

A similar test was run for ammonia (NH_3). The measurement instrument for both H_2S and NH_3 was a constant volume pump which pulled an air stream sample through a small disposable chromatographic column which had a color indicator in it. The unit was manufactured by Unico. Sampling time was 3 minutes.

Particulates coming out of the poultry house were measured using high-volume samplers (Sargent Welch Scientific Company). These samplers could pass about 0.033 cubic meters per second. It was found that in some cases as little as five minutes' sampling time was sufficient to overload the filter. Early tests were made using comparable high-volume gas samplers which were loaned to us by the Air Pollution Division of the Michigan Department of Natural Resources. That agency also processed these results. Since all of the air in the poultry house came to one point before exhausting to the outside, the obvious place to sample was in the vicinity of the exhaust fans.

In general, samples were taken just upstream of the fans and just downstream of the fans outside the building directly in front of the fan. Since differences between these two readings were not astounding, the later sampling program called for a single sampling point inside the tunnel just upstream of the exhaust fans. An early attempt to measure the particulate load in the afterburner exhaust ended in a disaster for the air sampler. Temperatures were simply too high for the air sampler unit. The particulate load collected by the high volume sampler is accurately weighed at standard temperature and humidity conditions. Tare weights on the filters are subtracted from final weights to give the particulate load collected over a certain time interval. The air-flow rate through the high-volume sampler is measured before and after sampling. An average flow rate is computed from these two readings. The particulate load can then be converted to micrograms per cubic meter. No attempts were made to classify the particulates according to their size. It was not uncommon to observe small feathers on the filters.

RESULTS

General

Three excreta samples were taken from each deck of four rows once weekly during the first five months. The results showed that the bottom and top decks had a similar excreta moisture, 73% as compared to that of middle decks, 74% (Table 4). When the excreta was removed from under cages to the pit at one end of the house, a slight reduction of excreta moisture (72%) was noticed. The excreta moisture was 65% after 20 hours on the conveyor belt in the drying tunnel. The excreta moisture was also found to be slightly different in various locations of the house. When excreta samples were taken from the row near the air intake wall, the moisture content was the lowest, 72%. Excreta samples taken from the row near the exit air wall had the highest moisture content, 74% (Table 5). From these results, it was evident that the in-house drying system with the fans in the drying tunnel achieved a moisture reduction of 15% from 80% (as voided) within 24 hours (Tables 4 & 6). This 15% drop in moisture content of the excreta represents a little more than 50% of the moisture present in freshly mixed manure. The effect of excreta dehydration in the drying tunnel was further evaluated when the dryer was put into operation. The heat generated from the dryer was channeled into the drying tunnel. The results of moisture determinations are presented in Table 7 for the period of December, 1973, to February, 1975. There was no explanation for the moisture reduction between samples taken under the cages and fresh excreta samples on the conveyor belt (Table 8). The time lapse between these two collections (under cages and on conveyor belt) was less than one half hour; however, the percent moisture difference was 5% (Table 8). The actual excreta moisture reduction was 11% within 24 hours dehydration in the drying tunnel. A 4% additional dehydration was realized while the excreta moved slowly toward the dryer (Tables 7 & 8). The affect of stirring can be noted in Table 9. During the period of data collection there appeared to be no additional moisture removal due to stirring. It was interesting to note that the moisture of excreta from the recycled feed group was consistently lower than the excreta from the control feed group, 73% and 74%, respectively (Tables 10 & 11). This difference is not considered important

TABLE 4. MOISTURE OF EXCRETA BY DECKS DURING JULY-NOVEMBER, 1973 (%)

Month	Bottom Decks*	Middle Decks*	Top Decks*	Pit	Conveyor Belt**
July	76	78	75	75	--
August	75	76	76	74	--
September	71	73	72	68	61
October	70	73	72	--	64
November	71	72	72	--	69
Average	73	74	73	72	65

*Average of 48 determinations
**On conveyor belt after 24 hours
--No samples were taken

TABLE 5. MOISTURE OF EXCRETA BY LOCATIONS, JULY-NOVEMBER, 1973 (%)

Month	Near Air Intake Wall *	Second Row	Third Row	Fourth Row (near exit air)	Pit	Conveyor Belt **
July	75	76	76	76	75	--
August	75	75	76	77	74	--
September	70	72	73	74	68	61
October	71	71	70	73	--	64
November	71	72	72	72	--	69
Average	72	73	73	74	72	65

*Average of 36 determinations
**Excreta moisture after 24 hours on belt
--No samples were taken

TABLE 6. DEHYDRATION OF EXCRETA IN THE IN-HOUSE DRYING SYSTEM, JULY-NOVEMBER, 1973 (%)

Month	Under Cages *	Pit	Conveyor Belt
July	76	75	--
August	76	74	--
September	72	68	61
October	71	--	64
November	72	--	69
Average	73	72	65

*Average of 144 moisture determinations
--No samples were taken

TABLE 7. THE EFFECT OF IN-HOUSE DRYING SYSTEM ON THE MOISTURE OF EXCRETA, DECEMBER, 1973-FEBRUARY, 1975 (%)

Month	Fresh Excreta On Board	Fresh Excreta On Belt	24 Hours On Belt	7th* Sample
12/73	72	72	--	--
1/74	74	71	--	--
2/74	74	71	--	--
3/74	75	69	65	--
4/74	73	68	63	58
5/74	74	68	61	59
6/74	71	65	50	43
7/74	66	66	56	50
8/74	75	67	62	60
9/74	72	68	62	60
10/74	72	67	65	65
11/74	74	70	69	69
12/74	74	70	69	67
1/75	74	70	61	--
2/75	74	69	62	--

*Sample taken immediately before reaching the hopper of the dryer
--No samples were taken

TABLE 8. THE EFFECT OF IN-HOUSE DRYING ON EXCRETA MOISTURE, DECEMBER, 1973-FEBRUARY, 1975

Location In the House	Moisture Content (%)	Percent Dehydration
Under cages	74	--
Fresh Excreta on Belt	69	--
24 Hours on Belt	63	11
Additional Drying*	59	15

*Drying when dryer was in operation. Samples collected immediately before reaching the hopper of the dryer.
--No samples were taken

TABLE 9. THE STIRRING EFFECT ON EXCRETA MOISTURE ON THE CONVEYOR BELT (%)

Month	Non-Stirred		Stirred	
	Fresh	24 Hours	Fresh	24 Hours
3/74	68	65	70	67
4/74	66	63	68	63
5/74	67	62	68	59
6/74	65	54	66	46
7/74	65	57	67	55
8/74	67	62	67	61
9/74	68	62	69	61
10/74	67	64	67	65
11/74	70	69	70	69
12/74	70	70	69	68
1/75*	--	--	70	61
2/75*	69	60	69	63

*See modifications section
--No samples were taken

TABLE 10. THE EFFECT OF ANAPHAGE ON THE EXCRETA MOISTURE OF LAYING HENS ON A MONTHLY BASIS (%)

Month	Recycled Feed	Control Feed	Average Moisture
3/74	74	76	75
4/74	72	73	73
5/74	73	74	74
6/74	71	71	71
7/74	72	74	73
8/74	73	76	75
9/74	72	72	72
10/74	72	72	72
11/74	74	74	74
12/74	74	74	74
1/75*	73	74	74
2/75*	74	73	74

*See modifications section

TABLE 11. THE EFFECT OF ANAPHAGE ON THE EXCRETA MOISTURE

Feed	Moisture Content (%)
Control Feed	74
Recycled Feed*	73

*Feed containing 10% anaphage

TABLE 12. ANAPHAGE MOISTURE

Month	Anaphage Moisture (%)
2/74	1.0
3/74	1.4
4/74	3.9
5/74	1.2
6/74	5.6
7/74	9.0
8/74	13.6*
9/74	5.3
10/74	5.1
11/74	3.5
12/74	13.3*
1/75	5.0
Average	5.7

*Mechanical problem in the dryer

TABLE 13. DRYING EFFECT OF THE IN-HOUSE SYSTEM

Method of Dehydration	Drying Effect*
Time:	(%)
24 Hours on Belt	9
Additional Drying*	13

*Drying while moving slowly toward the dryer when dryer was in operation because the difference may have been caused by physical location, i.e. the recycled group was located near the air-intake wall. The moisture of anaphage from this in-house system was also determined and is presented in Table 12. The average moisture content of anaphage for a 12-month period was 5.7%, ranging from 1 - 13.6%. The dryer functioned differently during the months of August and December, 1974, which resulted in a higher moisture content in anaphage, 13.6% and 13.3% respectively.

Anaphage samples taken during the month of February, 1975, were excluded in Table 12 because the temperature setting of the dryer was being evaluated in relation to the microbiological analyses.

The effect of in-house drying system is summarized in Table 13. The excreta moisture was reduced by 9% when left on the conveyor belt for 24 hours. An additional drying effect of about 4% was realized when the dryer was in operation.

Engineering Aspects

The moisture removal capability of a ventilation system depends on the initial temperature and humidity of the air as it enters the building, and the temperature and humidity maintained in the building. The condition of the incoming ventilation air is thus dependent on climatic conditions. The average monthly Michigan (East Lansing) temperatures are shown on the Figures 12, 13 & 14. The temperature of the experimental house was maintained at approximately 13° to 16°C (55° to 60°F) and the humidity at less than 75% during the cold months. During the warmer months the house environmental temperature consistently ran a few degrees above outside temperatures. The optimum summer ventilation system is one that keeps inside temperatures a minimum margin above outside temperatures. To prevent undesirable hot weather in-house temperature increases, the sensible heat from the birds must be used for evaporating moisture. The total bird heat is thus converted to latent heat so it does not increase the house environmental temperature. The ventilation system of this experimental house attempted to maximize evaporation during all seasons for 1) the maintenance of an optimum environment, and 2) to reduce the moisture content of the excreta.

The drying of excreta in the experimental house was summarized on a monthly basis over a period of one year and the results are shown by Figures 12, 13 & 14. These summarized results were obtained from hundreds of excreta moisture samples. Figure 12 shows graphically in percent moisture content (wet basis) the amounts of excreta drying 1) on the dropping boards and in the pits, 2) through movement of excreta, 3) on the belt in the drying tunnel, and 4) by the oil-fired mechanical dryer. The bottom curve indicates the final moisture content of the dried poultry waste. This moisture level ranged from extremes of 2% to 25% wet basis (w.b.). The top moisture content line of the graph is 80% and represents the moisture content (wet basis) of freshly voided excreta as measured during this investigation. The average monthly climatic temperatures in central lower Michigan are also plotted on this graph in order to show seasonal trends.

Moisture percentage calculated on a wet basis misrepresent the true

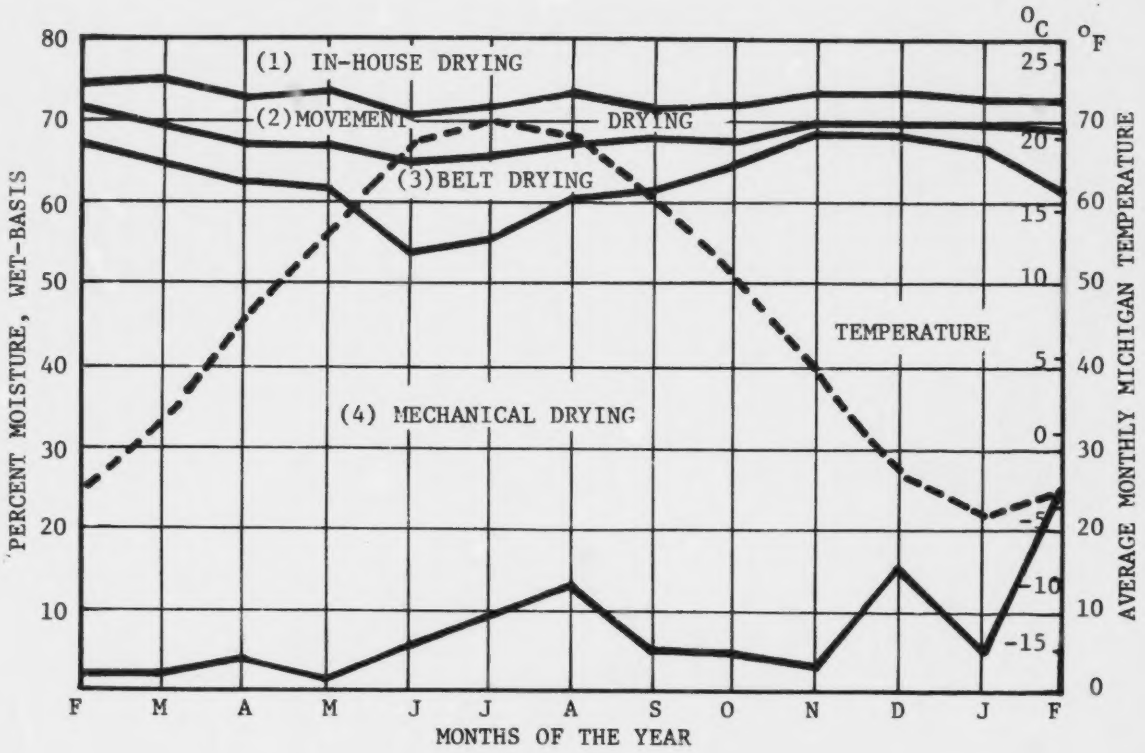

Figure 12. Moisture content percentage (wet-basis) change in excreta during the dry phases.

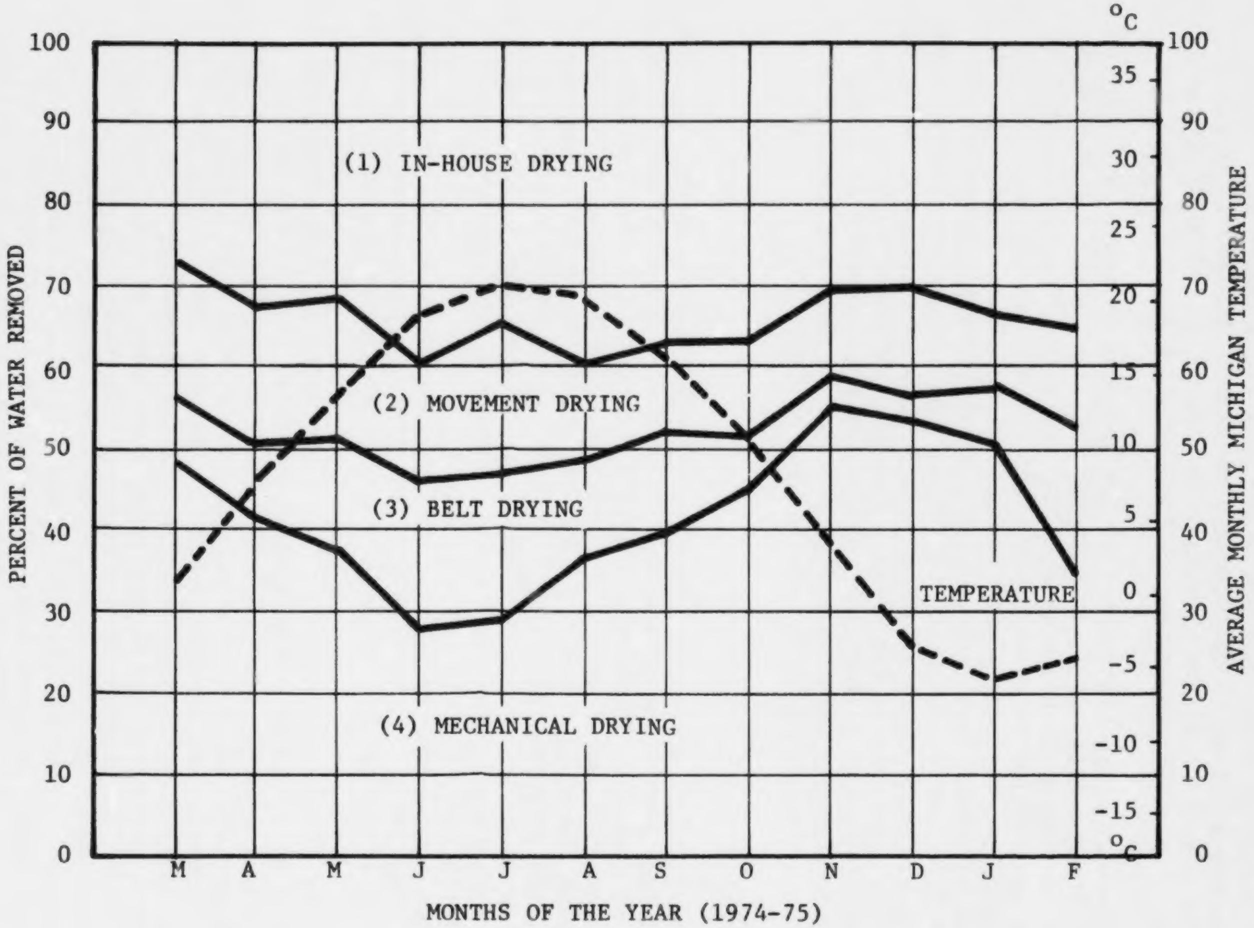

Figure 13. Proportion of excreta water removed in the four drying phases of the experimental house.

amount of water removal by various drying processes, so Figure 13 was prepared. This graph presents the proportion of the total water removal accomplished by each of the 4 drying processes or phases. The proportion of the excreta drying that took place in the house is shown by the top part of the graph. It should be noted that the in-house drying reduced the excreta moisture to below 70% quite consistently throughout the year. In other words, about one-third of the excreta water removal was done by the ventilation air as it normally moved through the cage-type poultry house.

The somewhat surprising aspect of the in-house drying by ventilation air was 1) its quantity and 2) that it was not significantly season dependent. The consistent in-house evaporation prevailed in spite of the fact the winter ventilation rates were much less (down to one-tenth) than for the summer months, and that the winter in-house air of from 13° to 16°C (55° to 60°F) could hold much less (approximately one-half) water vapor than the warmer air (27°C, 80°F, or above) during hot weather. Also, the in-house ventilation air must absorb all of the water vapor dissipated directly from the metabolic processes of the birds. The respired water vapor can amount to some 3 times the water evaporated from the excreta. A ventilation air psychrometric analysis of 3 typical months (Sept., Oct. and Nov., 1973) of the experimental house operation can be seen in Table 14.

Movement Drying

The movement of the excreta by conventional cleaning methods of scrapers and flight-type cross conveyors proved to be a very effective way of reducing the moisture content. The movement moisture reduction during the pit cleaning operation was documented by taking 8 excreta samples daily from locations below the cages. Immediately after the in-house daily sampling procedure, the dropping board and pit excreta was scraped into the cross conveyor, moved to the belt and spread to a uniform depth. Then, immediately after the excreta was spread on the belt another set of moisture samples were regularly taken. There was consistently a 3 to 4% reduction in moisture content (wet basis) that could only be accounted for as water loss during movement. The percentage (wet basis) reduction during movement is plotted on Figure 12 and shown as a proportion of total water removal on Figure 13.

The loss of water by scraping, cross conveying and spreading shows up on Figure 13 as a very significant portion of the total water removal. During the last 6 months (August, 1974, to February, 1975) of the experimental project when the entire operation was somewhat more stable than for the first 6 months, the movement water losses were consistently from 12 to 14% of the total excreta water removed. To further document the movement water losses, additional moisture samples were taken on 2 different days as shown by Table 15. Samples as indicated by line number (3) (Table 15) were taken at the end of the pits where the scraper dumped the excreta into the cross conveyor. Likewise, the line number (4) (Table 15) samples were taken at the point where the cross conveyor dumped the excreta onto the belt. A little variation of a percent or so is in evidence between these 2 different sampling days which is within the sample accuracy of this investigation. The data do show, however, that each of the movement operations accounts for a portion of the water losses. In general, one percentage point (wet

TABLE 14. THE PSYCHROMETRICS OF THE VENTILATION AIR AND ITS WATER REMOVING ABILITY

Month	(1) Avg.[1] Temp. °C (°F)	(2) Avg.[1] Hum. %	(3) h_o[2] Btu/lb.	(4) W_o[3] lb./lb.	(5)[4] Avg. House Temp. °C (°F)	(6)[4] Avg. House Hum. %
Sept.	17 (62)	69	23.6	.0080	19 (67)	65
Oct.	11 (52)	70	18.8	.0058	14 (57)	70
Nov.	3 (37)	76	12.7	.0035	13 (55)	70

Month	(7) h_i[2] Btu/lb. (Kcal/kg)	(8) W_i lb./lb. (kg/kg)	(9) H_2O Removed Belt lb./day (kg/day)	(10) H_2O[5] Removed In House lb./day (kg/day)	(11) H_2O[6] Latent Heat lb./day (kg/day)	(12) In house To be Removed lb./day (kg/day)
Sept.	26.2 (14.5)	.0092	415 (189)	470 (213)	1680 (765)	2150 (977)
Oct.	21.4 (11.9)	.0070	245 (111)	565 (257)	1500 (682)	2065 (940)
Nov.	20.3 (11.3)	.0065	175 (80)	470 (213)	1440 (655)	1910 (870)

Month	(13) H_2O To Be Removed lb./hour (kg/hour)	(14) H_2O Removed lb./hour/hen (gm)	(15) Bird[6] Heat Production Btu/hour (Kcal/hour)	(16) Δh Btu/lb. (Kcal/kg)	(17) ΔW lb./lb. (kg/kg)	(18) M^{Air} To Move Water lb./hour/hen (kg/hour)
Sept.	90 (41)	.0180 (8.2)	40 (10.1)	2.6 (1.4)	.0012	15.00 (6.8)
Oct.	85 (39)	.0169 (7.7)	40 (10.1)	2.6 (1.4)	.0012	14.10 (6.4)
Nov.	80 (36)	.0160 (7.3)	40 (10.1)	7.6 (4.2)	.0030	5.33 (2.3)

Month	(19) cfm/hen (M^3/hour)	(20) Sp. Vol. At t_i ft.^{3}/lb. (M^3/kg)	(21) Heat For Vent Btu/hour/hen (Kcal/hour)	(22) Cond. Heat Loss Btu/hour/hen (Kcal/hour)
Sept.	3.38 (1.60)	844 (13.5)	39.0 (9.85)	0.6[7] (.15)
Oct.	3.10 (1.47)	822 (13.15)	36.5 (9.22)	0.6 (.15)
Nov.	1.16 (0.55)	819 (13.1)	40.6 (10.2)	3.3 (.83)

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[1] Weather Bureau data for East Lansing, Michigan

[2] h is the enthalpy of the air in Btu/lb. of dry air

[3] W is the absolute humidity of the air in lb. of dry air

[4] Estimated average house temperatures

[5] Voided moisture content at 80% W.B.

[6] Handbook data from OTA

[7] Conduction heat loss of 580 Btu/°F U = 0.1 Btu/hour - Pt^2 - °F

basis) of moisture is lost by each movement operation (scraping, conveying and spreading).

Belt Drying

The reduction of excreta moisture content while on the belt throughout a 24-hour period in the drying tunnel is shown by the No. 3 phase, the area between the curves on Figures 12 & 13. The belt drying phase under conditions of this experiment was definitely season dependent. Belt drying accounted for up to 18% of the total excreta water removal during some of the summer months. During the latter winter months (October to January) of the investigation, the belt drying accounted for only from 4 to 6% of the total excreta water removed. The seasonal difference causes the difference in the drying potential of the exhaust air from the poultry house (Figures 12 & 13).

Additional drying aids were investigated during the last month of the investigation (February, 1975). It was shown that the maximum drying capability of the house exhaust air had not been previously attained even during cold weather. The excreta drying while on the belt for February, 1975 (see Figure 12) was about 18% of the total excreta moisture removal. This water removal equals the maximum attained during any summer month of the investigation. The increased excreta drying on the belt was accomplished with added air turbulence over the excreta.

Heated Air Mechanical Drying

The fourth drying phase was that accomplished with an oil-fired dryer. In order to improve the efficiency of this mechanical dryer, its exhaust gases, as well as those from the afterburner, were directed down the tunnel for additional excreta drying. Moisture samples indicated that the waste dryer heat contributed to additional excreta drying of from 1 to 2 percentage points (wet basis) during the 3 to 4 hours of daily dryer operation.

The highly significant aspect of the experimental in-house manure handling and drying system was that during the summer months only from 1/4 to 1/3 of the total original excreta water remained to be removed by an oil-fired, heated air dryer. Even during the winter months up to nearly half of the excreta moisture was removed by the in-house drying systems prior to its introduction to the machine dryer. With the added turbulent air drying aid introduced in February, 1975, the remaining excreta water throughout the winter months could be reduced to the summer level of 1/3 of the total. No doubt, with the turbulent air drying aid during the summer months, the remaining excreta moisture for machine drying could be further reduced to well within 1/4 of the total.

Heated Air Dryer Performance

Machine heated-air drying of poultry excreta has not yet been developed into a very efficient process. When an afterburner is used, along with the oil-fired air heater for minimizing air pollution, as in this investigation, an equivalent fuel heat content of from 2208 to 2760 Kcal/kg (4 to 5,000

TABLE 15. THE LOSS OF EXCRETA WATER BY MOVING FROM DROPPING PITS TO BELT

		% M.C. w.b.	
	Site	January 20	February 8
(1)	On the dropping boards	73.7	73.0
	% Difference	0.9	0.0
(2)	In the dropping pits	72.8	73.0
	% Difference	1.3	0.7
(3)	As scraped from pits	71.5	72.3
	% Difference	0.4	1.9
(4)	As conveyed onto belt	71.1	70.4
	% Difference	0.4	1.4
(5)	After spread on belt	70.7	69.0
	Overall percentage change	3.0	4.0

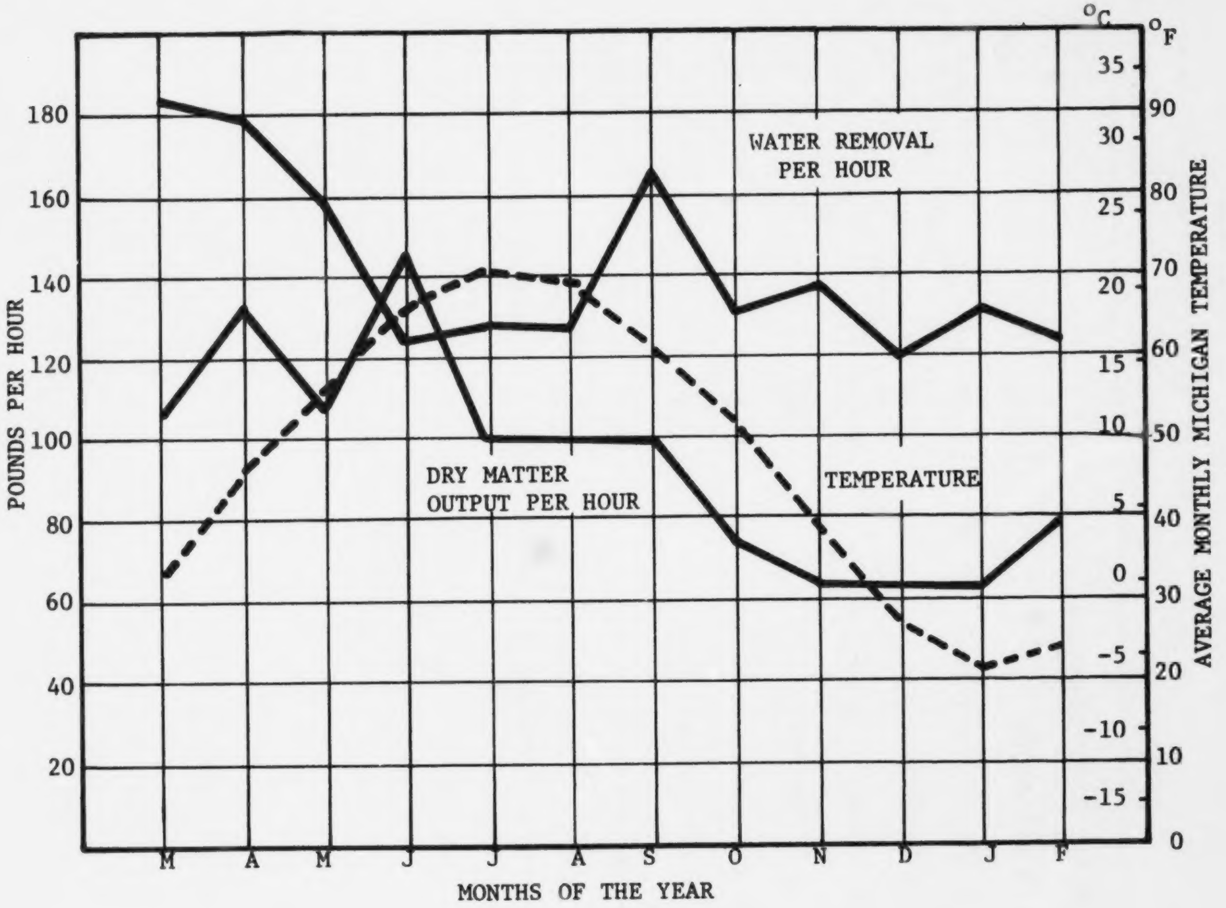


Figure 14. Dryer performance on a monthly basis.

BTU) was required to remove each pound of excreta water. Approximately 1,000 BTUs of heat are required at 100% efficiency to evaporate 552 Kcal/kg (1 lb.) of water; thus, a machine drying efficiency of from 20 to 25% was accomplished. Elimination of the afterburner, if acceptable from a pollution control standpoint, could double the fuel utilization efficiency. This was shown to be the case during February, 1975. See the bottom line of Table 17 in which the afterburner was not functioning and the fuel heat-equivalent was 1290 Kcal/kg (2,300 BTUs per pound) of excreta water removed.

The performance characteristics of the heated air dryer are shown by Figure 14. The critical criterion of a dryer is the amount of water it will remove per hour. A reliable mechanical dryer should perform quite independently of the season of the year and the moisture content of the input excreta. This statement is made in view of the fact that some additional dryer heat losses could be expected during cold weather and that the last few percentage points of moisture are the most difficult to remove. For the last 9 months of operation, as shown by Figure 14, the machine dryer water removal rate was quite consistently about 59 kg (130 lbs.) per hour for all except one month (September). This seasonal independent period extends from summer months through the coldest winter months. About 1/10 of a pound of H_2O per day per bird must be removed (Table 16). Therefore, the dryer capacity would be about 10,000 birds per 8 hour day at 67% excreta moisture and about 20,000 birds per 8 hour day at 50% excreta moisture. The much better water removal performance of the dryer during the first three months of the investigation (see Figure 14) cannot be explained by other than possibly the better performance of the new (just fabricated) dryer for a brief period and/or by the unrealiability of the measurement data (may have been due to inadequate sample numbers) during the early months of the investigation. If the water removal capability of a dryer is constant throughout all months of the year, then the dry matter output must vary seasonally with the moisture content of the incoming excreta. As shown in Figure 13, the moisture content (wet basis) of the excreta going into the dryer was down to the 55% range during the summer months and as high as 68% during the winter months. For comparison purposes, a 50% moisture content (wet basis) sample contains only 1/2 as much water as a 67% sample. Much more dry matter per unit time was thus produced by the machine dryer during the summer months. This is shown to be the case quite consistently during the last 9 months of stable operation of the experimental house (see Figure 14).

Fuel Cost For Machine Drying

The fuel cost of the machine removal of excreta water was about 2.2¢/kg (1¢/lb.) during the in-house drying investigation. This cost is based upon a fuel oil cost of 9¢/liter (34¢/gallon) and an assumed equivalent heat content of 9,620 Kcal/liter (144,000 BTU/gallon). For 5,000 laying hens the daily fuel oil cost for machine drying of the excreta from 67% to 5% (wet basis) was $5.38. This cost was reduced by about 1/2 by pre-drying the excreta in the house to a 50% level before it goes into the dryer. Over the one year operational period for this experimental project the excreta dry-matter output per laying hen averaged 24.7 gm/day/hen (0.0543 lb./day). The calculated voided weight of excreta at 80% (wet basis) was then 123 gm/day/hen (0.272lb./day/hen) and the total water to be removed in drying the excreta to 5% was 97.6 gm/day/hen (0.2147 lb./day/hen).

TABLE 16. EXCRETA PRODUCTION OF BIRDS

Observation	G/day/hen (lb./day/hen)	kg/day for 5,000 hens (lb./day for 5,000 hens)
Excreta dry matter	24.7 (.0543)	123.5 (271.5)
Excreta wt. @ 5% m.c. w.b.	26.1 (.0573)	130.0 (286.5)
Excreta wt. @ 80% m.c. w.b.	123.0 (.272)	618.0 (1360.0)
Total water to be removed in reducing excreta m.c. from 80% to 5%	97.6 (.2147)	488.0 (1073.5)
Total water to be removed in reducing excreta m.c. from 67% to %5	49.0 (.1077)	244.0 (538.5)
Total water to be removed in reducing excreta m.c. from 50% to 5%	23.4 (.0517)	117.5 (258.5)

Particulate Emissions

The results of repeated observations of the odor level in the building are that at no time were the odors from Building 7 even approaching an intolerable level. Odors were at their strongest (but not necessarily most offensive) during drying. The quality of such odors can best be described as a mixture of unburned kerosene and burnt beefsteak. The afterburner was ineffective in controlling odor.

Odors in the feed room, where anaphage was stored in barrels, could be detected at a dilution of 7:1. Odors in the dryer room itself could be detected in the charcoal-filtered air stream. This means that the charcoal filtration was insufficient to remove the fuel oil odor from the air; hence, no dilution is reported. In the center of the building, a 30-fold dilution was the odor threshold level. At the southeast corner of the building, a 200-fold dilution was the odor threshold; the position in that corner of the building was just above the manure cross-conveyor. A measurement made in the tunnel also came through with the charcoal-filtered air, making a dilution number impossible to report. That measurement was made with the dryer and afterburner in operation. The afterburner temperature was 540°C.

Measurements of hydrogen sulfide in the poultry house were less than

0.5 ppm even at points in the building where odors were at their strongest. Sampling points selected in the building were those positions where it was felt that "manure odor" was the strongest. Even so, at 3 locations, viz. just above the manure hopper of the dryer, in the gutter which conveys manure across the building, and at one point mid-building at the air slot, no hydrogen sulfide concentration could be detected which was above the minimum sensitivity of our instrument. Hydrogen sulfide concentration was in all cases less than 0.5 ppm. The ammonia concentration was consistently less than 1 ppm.

Particulate data are presented in Table 17. These data indicate that the afterburner was partially effective at best. It is interesting to note the high emission rate when the dryer/afterburner was off. This is to be compared with a background (fresh outside air, presumably inlet air) of 75 $\mu g/m^3$, a conservative (high) value for Lansing received from the Air Pollution Agency mentioned above. In considering the table, bear in mind that the air pollution primary standard for particulate emissions is 75 $\mu g/m^3$.

The especially high pariculates measured in May are probably caused by too high a dryer temperature and smokey operation. Dryer temperature settings of 175°C or less resulted in clean operation, i.e., internal firing of anaphage deposits in the dryer did not occur. On the other hand, the product was dried to perhaps 15% moisture content. At 15% the microbiologist reported bacterial counts in dried material that were higher than counts for drier material. Also, the afterburner temperature was low. As a result of high temperature dryer operation, the afterburner became laden with soot. The soot was re-entrained by the airstream even when the afterburner was cold. The afterburner seldom got sufficient fuel for the dryer load; when attempts were made to increase fuel flow, the device starved for air. Hence, the smokey sooty operation and the odor of unburned fuel.

The 20 August data show that the afterburner temperature had been increased, but smoke episodes would still occur which would swamp the afterburner. The smoke was caused by the dryer. Air samples taken at the end of the tunnel on 10 and 12 January, 1975, show the effect of soot accumulation in the afterburner. (Before soot removal 26,500 $\mu g/m^3$; after soot removal about 5,400 $\mu g/m^3$.) When the afterburner was operating at 540°C, however, the particulate load was not significantly different from the dryer-only situation. Large particulates accumulated in the tunnel when the afterburner was bypassed. This suggests that the afterburner was acting as a settling chamber in those cases where reduction of particulates was observed. In the other (more usual) cases where particulates at the end of the tunnel were not reduced, we theorize that the afterburner trapped large particulates and converted them into smaller particulates since settling in the tunnel was not so obvious.

It is important to recognize the importance of particulate emissions when neither dryer nor afterburner was operating. These "background" emissions are going on 24 hours a day. Four hours' drying emissions are small compared with the steady rate of output from the caged layer operation itself. It is interesting to note that an increased ventilation rate tends to increase the air-borne particulate concentration pointing towards the mechanism of particle re-entrainment. Particulates, presumed to be feed and feather particles, were not analyzed.

To scale this dehydration system up to production scale operation, the estimated particulate emission levels should probably be based on an "average ventilation rate" of 11 m^3/sec. The corresponding "normal" emission level would be on the order of 5000 μg/m^3 for a total load of 198 g/hour during dryer operation. With the dryer off for a portion of the day, emissions during those times would be based on about 4000 μg/m^3 for a total of 154 g/hour emitted. Odors in a scaled-up unit should be no worse inside the buildings than they were in our 5000 bird unit. Manure residence times would be the same in large scale. Whether odor (and particulate) emissions would be more offensive from a 500,000 bird operation is debatable; odor quality should be the same and concentrations should be about the same. Efficient ventilation could hardly bring the entire exhaust stream to a point discharge.

TABLE 17. PARTICULATE EMISSIONS FROM BUILDING NO. 7

Date	Outside temp.	Conditions Afterburner/Dryer	Ventil. rate (m^3/sec.)	Particulate concentration ($\mu g/m^3$)
15 May (rainy, humid)		Afterburner ON 370°C Dryer ON	10	24300/31400**
		Afterburner OFF Dryer ON	10	42100/33400**
		Afterburner OFF Dryer OFF (i.e., air from house only)		8720/11200**
20 Aug.	29°C	Afterburner ON 425°C Dryer ON		2340/6940**ε
		Afterburner OFF Dryer ON		7910
20 Nov.		Afterburner OFF Dryer OFF		3230
10 Jan.		Afterburner ON Dryer ON		26500+
12 Jan.		Afterburner ON 540°C, soot removed Dryer ON		5200/5600
25 Jan.	5°C	Afterburner BYPASSED Dryer ON		5990/5310/7100ε
		Afterburner BYPASSED Dryer OFF		4080/3870/3850ε

**replicates
ε 5, 10, and 15 m^3/sec., respectively
+ smoke episode

SECTION 5

INTRODUCTION: MODIFICATIONS OF THE IN-HOUSE DRYING SYSTEM

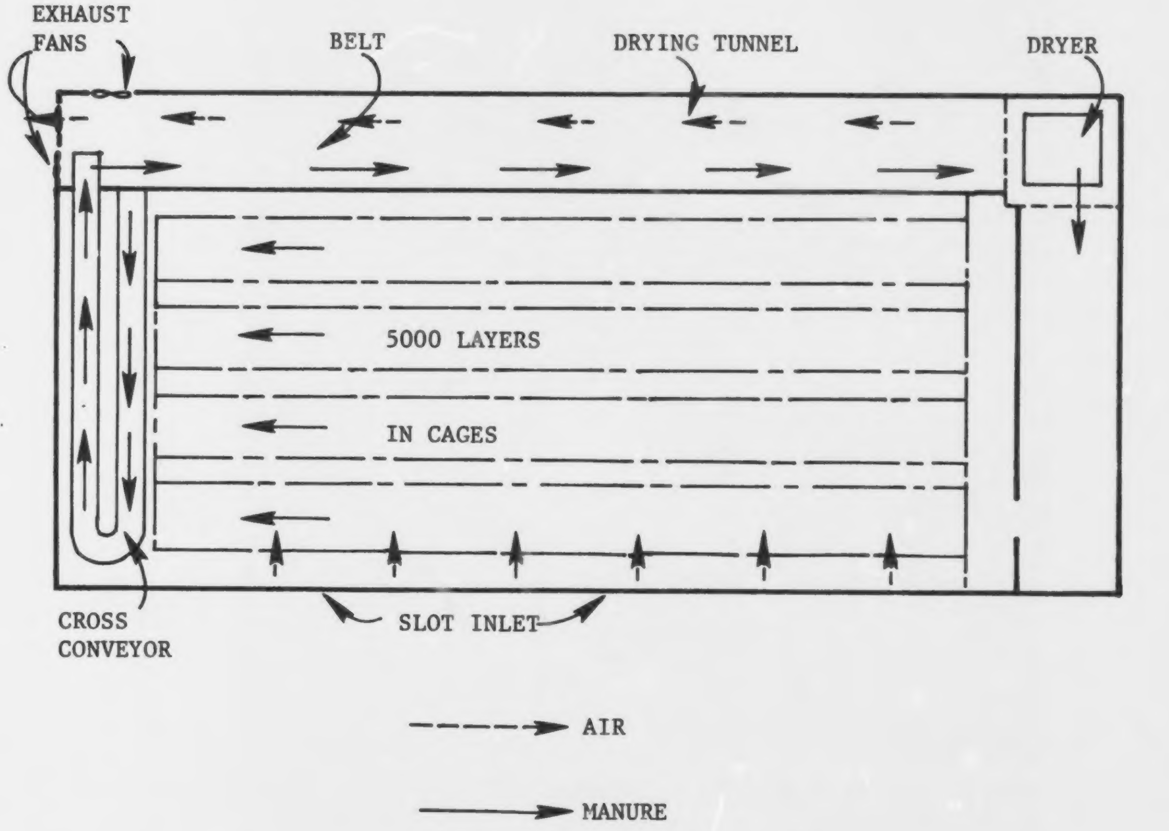
After approximately 18 consecutive months of operation, the in-house poultry excreta drying system (previously described in this report) was modified. It was evident that optimal drying was not being accomplished utilizing the original house design. It was also apparent that the cost of the afterburner operation was excessive and the emission control attributable to the afterburner was not satisfactory. The modifications, therefore, were made to: 1) improve in-house excreta drying capability, 2) decrease or eliminate the pollution emissions from the poultry house, and 3) eliminate the need for the afterburner on the oil-fired dehydrator (see Figure 15).

MATERIAL AND METHODS

Stirring Device Modification

The original stirring device (Figure 16) did not produce the desired effect of reducing the moisture content of the stirred manure and did not operate as expected. This device consisted of 3 rows of 1 cm diameter steel rods mounted on a wheeled harrow. There were 4 spikes spaced approximately 15 cm apart in each row. The spikes in each row were staggered to plow a different furrow then the row of spikes in front of it. In January, 1975, a new stirring device was installed. It was made of 10-gauge, galvanized rolling discs, 25 cm in diameter. There were 6 discs, 10.6 cm apart, on an axle that was set on an angle approximately 60^{o} to the length of the belt. The purpose of the disc stirring device was to turn, move and cut the excreta on the belt in order to expose more surface area to the air for drying. The data on stirring, in both cases, were only gathered from one-half (that nearest the exhaust fans) of the belt.

Each day when data were taken the manure was placed on the belt before 12:00 noon. The excreta was then stirred 2 times in the afternoon, at approximately 1:30 and 3:30 p.m. It was stirred again 2 times in the evening at approximately 7:00 and 9:00 p.m. The following morning the excreta was again stirred at 7:00 a.m. A complete round trip was made by the stirring device each time the excreta was stirred. Samples of manure for moisture determination were taken twice. The manure was first sampled when loaded on the belt (between 10:00 and 11:00 a.m.) and again from the same manure the following morning at approximately 9:30 a.m.



X = Recirculating fan locations

Figure 15. An experimental in-house system for handling and drying of poultry manure.

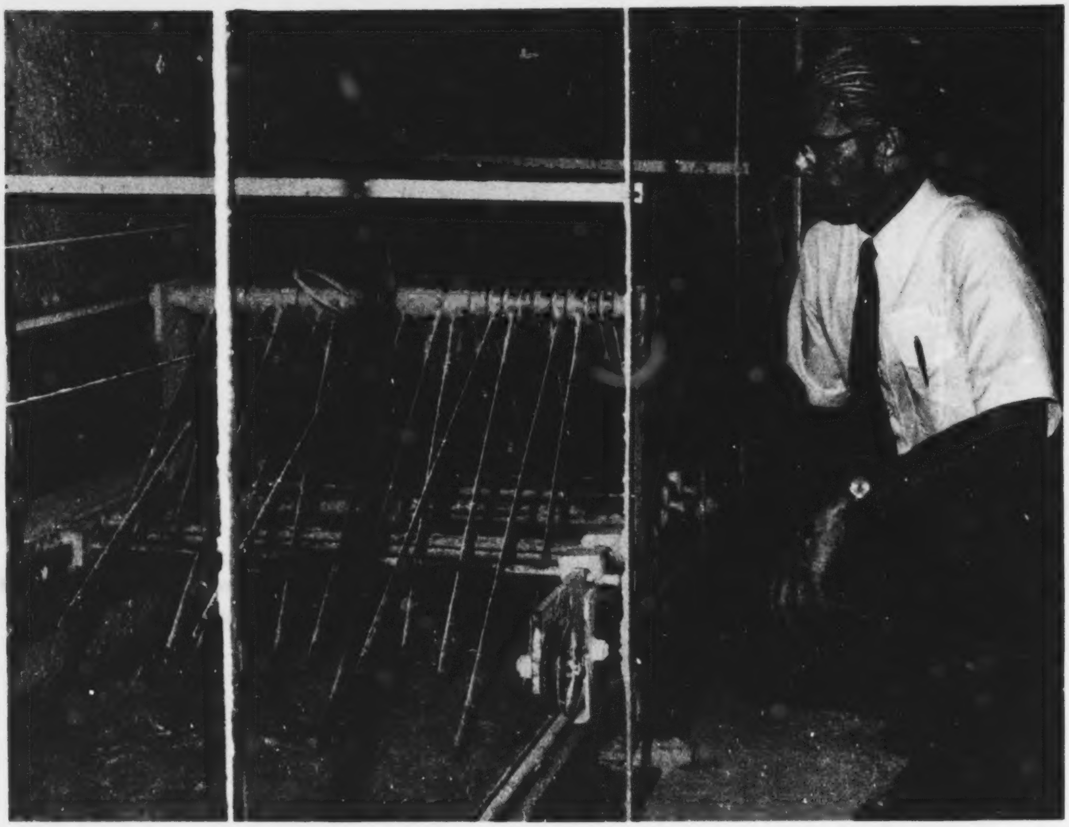


Figure 16. Researcher checking the original stirring device.

Recirculating Air Modification

Six, 35 cm, 6-bladed fans with 1/4 hp. motors were installed in the wall between the birds and the drying tunnel (just below the ceiling; see floor plan, Figure 15). They were placed approximately 4 m apart, with the first fan being placed about 4 m from the end of the cage row. Each fan was placed in a duct that was extended approximately 5 m to the middle of the aisle in the center of the house. The air ducts were 17.5 x 60 cm. The fans were hooded on the tunnel side of the wall with the hood extending down to within approximately 60 cm of the belt. The purpose of the hoods was to direct the air onto the manure. The cross section of the hood measured 42.5 cm x 42.5 cm. The volume of air produced by each fan was 21.9 cm/min. (Table 18).

Particulate Emission Modification

A tower, 2.4 m x 2.4 m x 7.2 m (Figure 17) was constructed and designed to receive all the exhaust air from a 5000-bird caged layer house. The exhaust air consisted of ventilation air as well as the exhaust of a small, oil fired dryer and afterburner that was used to dry poultry manure to anaphage.

At the base of the tower a tank was installed that was approximately 2.4 m x 2.4 m x 0.8 m. The purpose of this tank was to hold the waste water from the drinking troughs and to serve as a sump for the scrubber. Originally, tap water was added when necessary to maintain an adequate water level.

There was a space 2.4 m x 2.4 m x 2.4 m, immediately above the tank into which the exhaust air from the laying house was introduced. The upper 3.6 m (also 2.4 m x 2.4 m) contained about 418 m^2 of surface area. This surface area consisted of quart plastic bottles with part of the neck removed (to avoid some constriction). The bottoms of the bottles were also removed to allow air passage through the bottle.

The quart plastic bottles were placed in a honeycomb arrangement on trays (Figure 20) approximately 1 x 2 m. The bottles were stacked 3 tiers high (approximately 65 cm) in each tray. Two trays were placed on each level; one pair of trays at 2.4 m above the top of the tank; the second set of trays was placed approximately 1.25 m above the first; and the third set, approximately 1.25 m above the second set of trays. Between each tier of trays there was an open space of approximately 0.6 m to permit some air turbulence to develop.

The water from the tank was pumped to the top of the tower (Figures 18 & 19). It was then dispersed over the 418 m^2 of surface area to trap (or collect) particulate matter in the exhaust stream. Measurements were made on the particulates entering and leaving the filtration tower.

The original watering system consisted of a v-trough continuous flow waterer. However, due to excessive water spillage from the v-trough system, a new system was installed 6 months after the original system was put into operation. The new waterer consisted of a 10 cm wide aluminum, seamless trough. This was a standing water system with a 2.5 cm high overflow pipe at the end of each trough. Installation of this new system minimized water

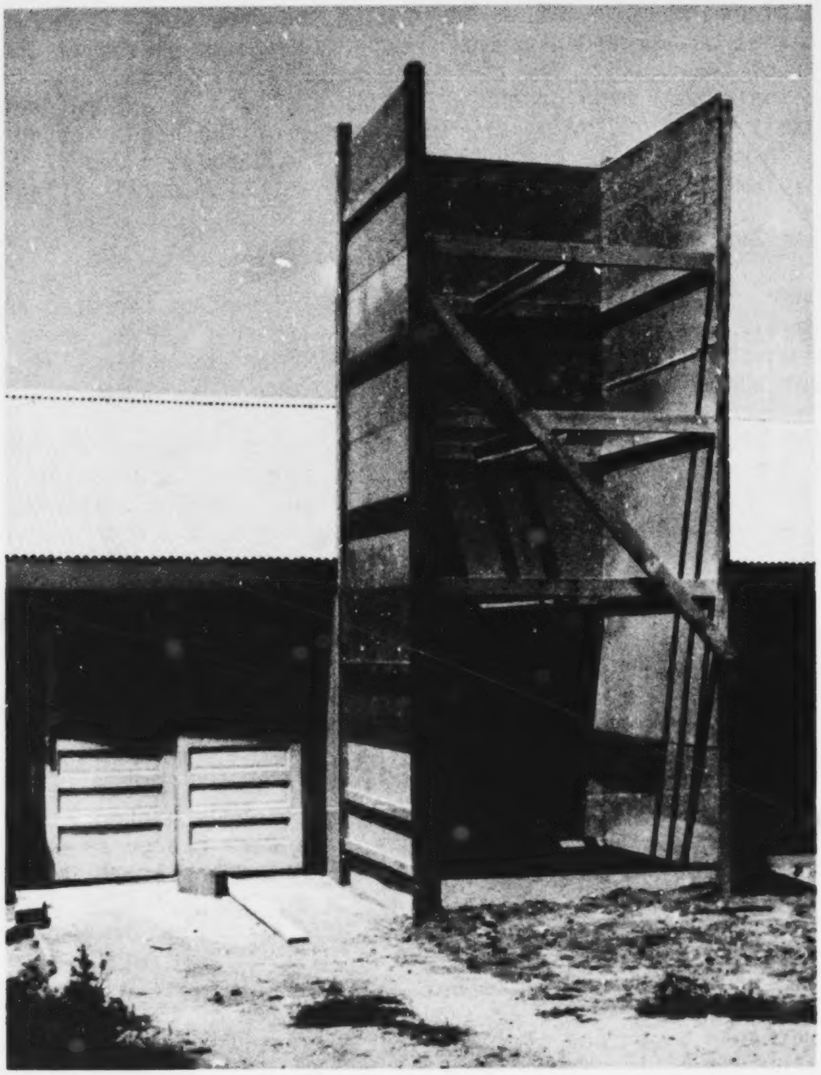


Figure 17. The scrubbing tower under construction.

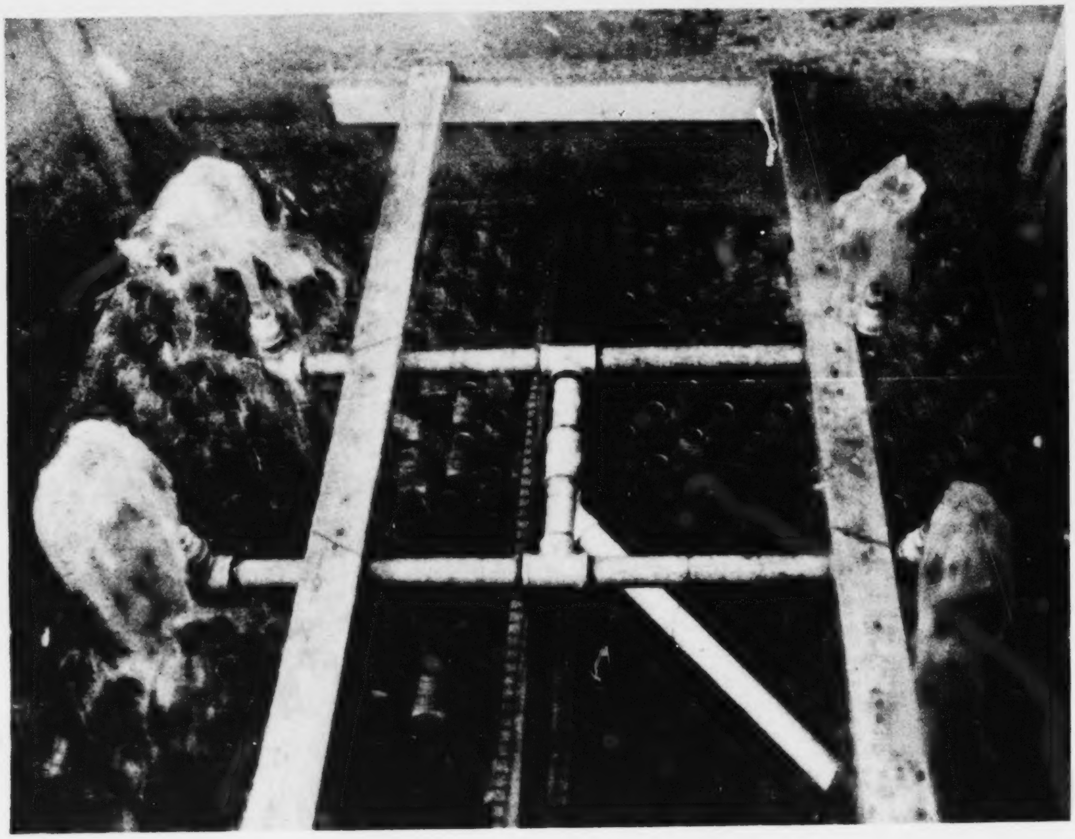


Figure 18. Liquid distribution system at the top of the scrubbing tower.

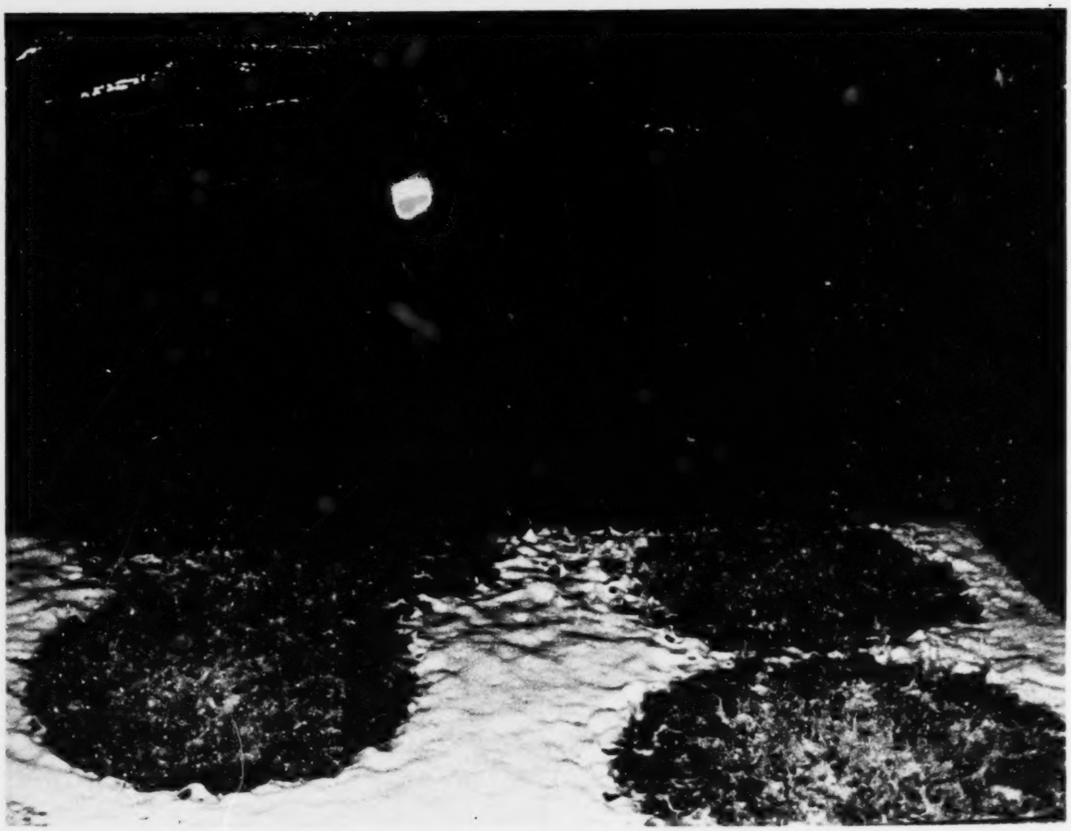


Figure 19. Pattern of liquid distribution at scrubbing tower base.

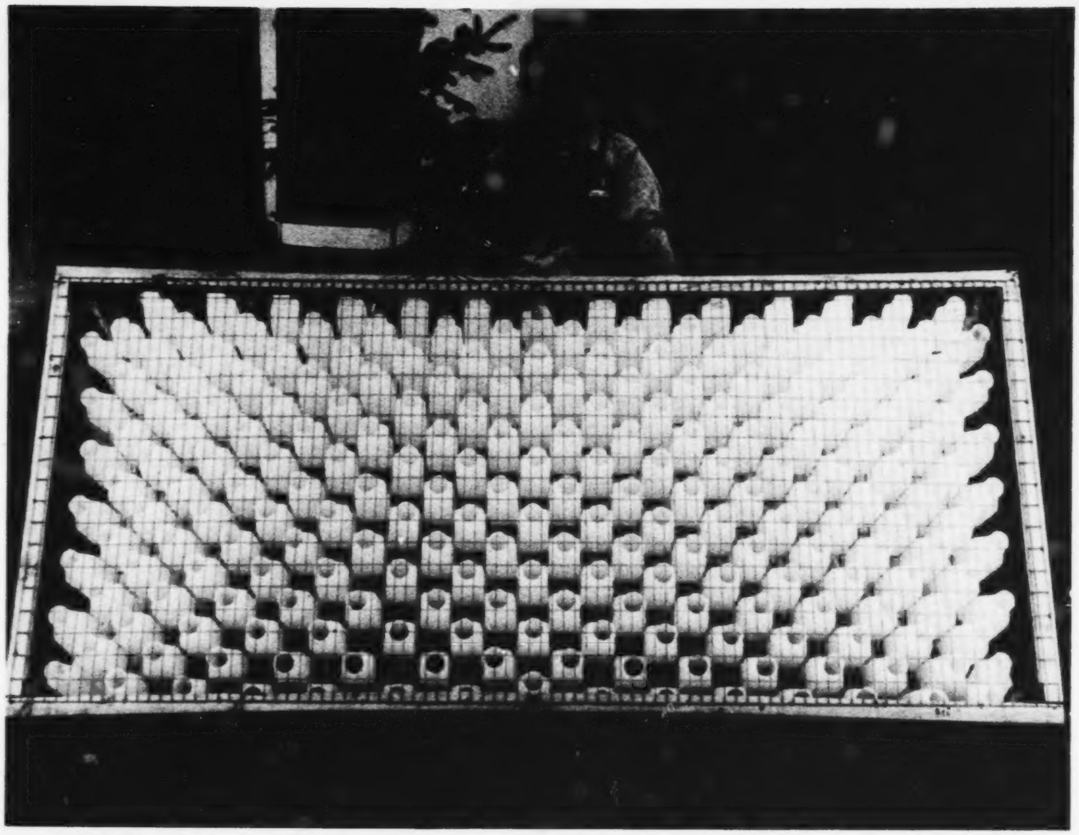


Figure 20. Scrubbing tower contained six of these trays.

TABLE 18. AIR FLOW READINGS (n=36) IN DUCT OF RECIRCULATING FANS (HOT WIRE ANEMOMENTER READINGS IN CUBIC METERS)

25.9	25.9	24.7	23.0	20.4	19.5	18.9	18.3	18.9	19.2	18.9	16.8
26.8	25.9	25.9	23.0	20.7	19.2	17.7	17.7	19.8	19.5	18.6	17.7
26.8	25.3	26.8	22.3	20.1	17.7	16.5	17.4	19.5	18.3	19.2	17.4

17.5 cm

60.0 cm

Area = 1050 cm^2
Average rate air flow = 209 m/min
Volume = .1050 x 19.3 = 21.9 m^3/min

spillage onto the floor and manure.

When the tower was built, the waste water line was intercepted. When the watering troughs were cleaned, the discharged water was pumped into the tank on an almost daily basis to maintain the water level in the tank.

Emission measurements were made by using high volume air samplers. Samples were taken at 2 locations. The first sample was taken just ahead of the ventilation fans that forced the air up the tower. The second sample was taken in the air stream at the top of the tower. The samples were taken both with the dryer off and with the dryer on.

The exhaust air at the top of the tower contained droplets of water. These droplets contained dissolved material and were measured as a part of the particulate emissions. The volume of air flowing through the tower was varied, depending on the number of 283 m^3 per minute fans that were operating.

In mid-January, 1975, the afterburner (Figure 21) was detached from the dryer. This was done by turning the elbow going from the dryer to the horizontal afterburner, one-quarter of a turn. This allowed the dryer to discharge its emissions directly into the drying tunnel.

Odor Modification

Odors are one of the major problems of large commercial egg production farms. Several attempts were made to measure odors in the house and at the top of the tower. One method that was used was personal observation by 3 researchers.

Another method of odor detection used was described by Jacobs (1960). This method consisted of bubbling a measured amount of air through a dilute sulfuric acid solution for ammonia detection. Air samples were taken at 3 sites; one, at the center of the laying house, approximately three-tenths of a meter above the floor level; the second site was located in the air stream as it entered the ventilation fans; the third site was located at the top of the tower to test the air as it left the scrubber.

Water Quality Measurements

Several measurements were made on the liquid medium used in the scrubber tower. The tests included chemical oxygen demand, total solids, volatile solids, electrical conductivity, total nitgrogen, ammonia and pH. Initially, the tank at the base of the tower was filled with tap water. Due to evaporation and droplet emissions, liquid was added to maintain a depth of 72.5 cm. Most of the additional water added was the discharge from the bird watering system. This water contained feed, feathers, fecal material, etc. (Table 23). Samples of the liquid in the tank and of the discharge water from trough cleaning, were taken periodically.

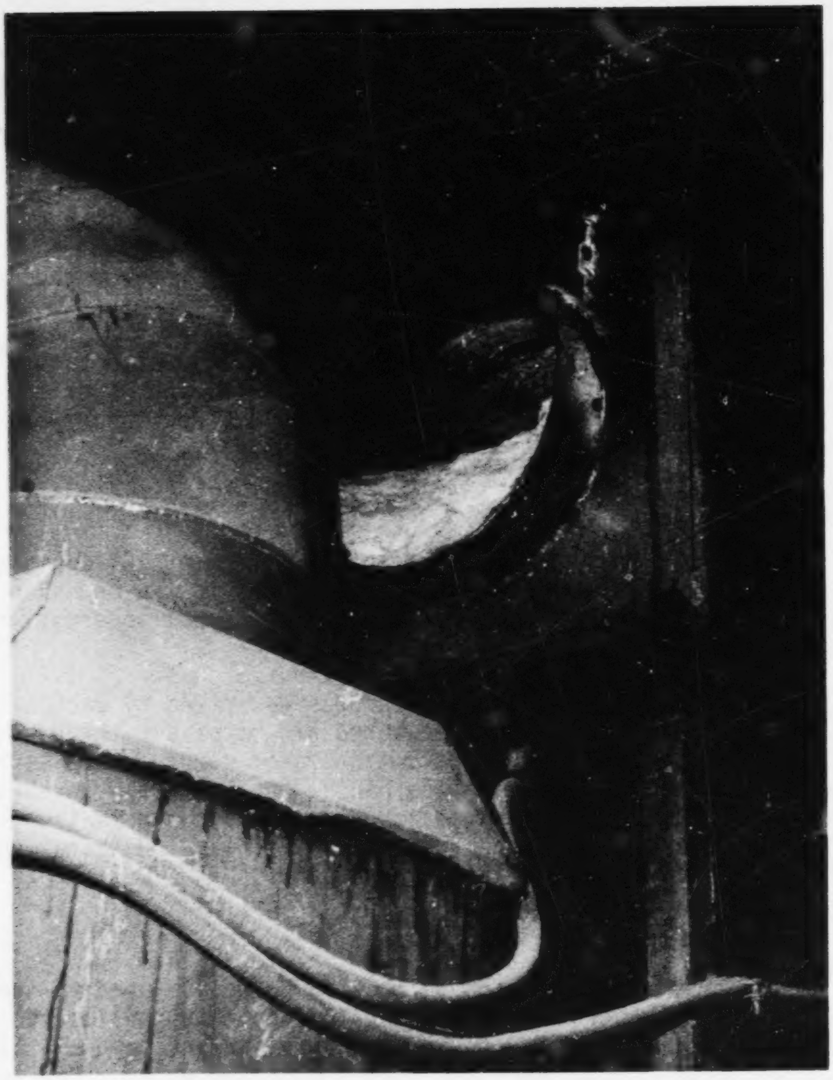


Figure 21. The inlet into the horizontal afterburner was partially clogged with particulates when it was disconnected.

RESULTS

Moisture Content of Stirred vs. Non-Stirred Manure

Moisture content of the stirred and non-stirred manure was very similar when the first stirring device was used. An average moisture content of the manure samples of 16 observations in the cool months of March, October and November of 1974 was 67.4% for the stirred and 65.6% for the non-stirred manure. The new stirring device produced tracks, valleys and ridges through all the manure on the belt as the belt was being loaded as well as when the manure was stirred. However, the new stirring device did not result in additional drying of the manure (Table 19) when compared with moisture of the manure from the non-stirred area.

The average moisture content of the manure samples on the half of the belt farthest from the exhaust fans (not stirred) was 57.4% after 24 hours on the belt. The manure on the half of the belt nearest the exhaust fans (the stirred portion) contained 61.7% moisture content after 24 hours on the belt.

Effect of Recirculating Air

Table 19 presents the results of the use of recirculation fans to help dry the manure on the belt. The odd-numbered sample locations refer to manure samples taken between fan outlets. The even-numbered sample locations refer to manure samples taken under the fan outlets. The average moisture content of the manure between fan outlets on the half of the manure not stirred was 61.5% and the half of the manure which was stirred contained 65.0% moisture. The average moisture content of the manure not stirred under the fan outlets was 53.1% and of the manure stirred was 57.5%.

Data from 3 days (Feburary 19, 1974 and February 11, 12, 1975) are presented in Table 20. These data show the limited amount of manure drying that takes place on the belt in 24 hours when the recirculation fans were not used. The 65 to 68.5% moisture content of the manure was reduced under the recirculation fans to 53 to 58%. The 10 to 16% moisture reduction means that up to 50% of the water in the 67% moisture content manure (typically present in manure on the belt in the winter) has been removed by the air from the recirculation fans.

Particulate Emissions

Presented in Table 21 are the data of airborne particulates for inlet and outlet concentration for 1 fan ($5m^3$/sec.), 2 fans ($10m^3$/sec.), and 3 fans ($15m^3$/sec.) with the dryer operating and with the dryer not operating. In all cases, the tower reduced the particulate load by 67 to 75%. The increased emissions during dryer operation were reduced to almost the same level as when the dryer was not operating. A large amount of particulate matter (Figure 22) exhausted by the dryer was not measured but was evident as debris in the drying tunnel. This debris dropped out of the air stream before reaching the ventilation fans (the first sampling site).

TABLE 19. PERCENT MOISTURE CONTENT (m.c.) OF EXCRETA ON THE BELT 24 HOURS (JANUARY & FEBRUARY, 1975)

Item	NON-STIRRED					
Sample Location	1	2	3	4	5	6
No. Readings	5	5	5	5	5	5
Avg. % Moisture	61.1	53.1	64.8	54.8	59.6	51.3
	STIRRED					
Sample Locations	7	8	9	10	11	12
No. Readings	15	15	15	15	15	4
Avg. % Moisture	66.1	54.2	65.6	59.5	63.4	60.2

Average, locations 1-6 = 57.5% m.c. (non-stirred)
Average, locations 7-12 = 61.5% m.c. (stirred)
Average between fans 1, 3 and 5 = 61.8% m.c.
Average between fans 7, 9 and 11 = 65.0% m.c.
Average under fans 2, 4 and 6 = 53.1% m.c.
Average under fans 8, 10 and 12 = 58.0% m.c.

TABLE 20. THE MOISTURE CONTENT OF POULTRY MANURE ON THE BELT AFTER 24 HOURS WITH NO RECIRCULATION FANS AND STIRRING vs. NON-STIRRING

Date	Treatment	Moisture Content	Treatment	Moisture Content
2/11/75	Non-stirred	65.0%	Stirred	67.0%
2/12/75	Non-stirred	68.5%	Non-stirred	67.1%
2/19/75	Non-stirred	68.0%	Non-stirred	68.0%

Odor

When the dryer was operating the odor of fuel oil could be detected at 2 sampling sites (at the ventilation fans and at top of tower). The odor of drying manure was also detectable at both sites when the dryer was operating. When the dryer was operating, the odors at the top of the tower were markedly less than at the inlet site. None of these odors were really objectionable to the odor panel (Gerrish, Sheppard and Flegal). During drying, there were some episodes of heavy smoke emissions. These were only partially clarified by the scrubber unit.

The results of the ammonia determination indicated that there was less than 1 ppm at all sites tested (Table 22).

Water Quality Measurements

As can be seen in Table 23, the chemical oxygen demand was 3900 mg/l at the start of operation of the scrubber unit. This dropped to 2300 mg/l after 20 days and then steadily increased to 8500 mg/l at 80 days. The same general pattern was observed in the electrical conductivity. Volatile solids in the liquid medium of the scrubber unit decreased from 3500 mg/l at 20 days to 2000 mg/l at 80 days. Total solids also dropped from 4700 mg/l at 20 days to 3500 mg/l at 80 days. The reduction of total solids correlates with droplet emissions from the top of the tower. Total nitrogen and NH_4^+ were variable during the time that measurements were taken. A general indication of the material balance in the scrubber unit is shown in Figure 23.

When the project was ended, a sludge blanket was found at the bottom of the liquid tank. The accumulated solids would account for the decrease in volatile solids observed toward the end of the operation. This sludge accumulation would eventually have necessitated a clean-out of the tank and a fresh start with new liquid.

Figure 22. Some particulate emissions (debris) in the drying tunnel.

TABLE 21. EFFECT OF THE ADDITION OF A SCRUBBER TOWER ON PARTICULATE EMISSIONS, JANUARY 25, 1975 (AFTERBURNER WAS BY-PASSED)

Dryer	Flow m^3/sec.	Inlet Particulate Concentration (μg/m^3)	Outlet Particulate Concentration (μ/m^3)
Off	5	4080	1350
	10	3870	1810
	15	3850	1320
On	5	5990	1400
	10	5310	1440
	15	7100 (smoke episode)	2780

TABLE 22. AMMONIA CONCENTRATION IN PPM OF AIR SAMPLED (AVERAGE OF TWO SAMPLES)

Position	Ammonia ppm
House center	.59
Before fans	.54
Top tower	.72

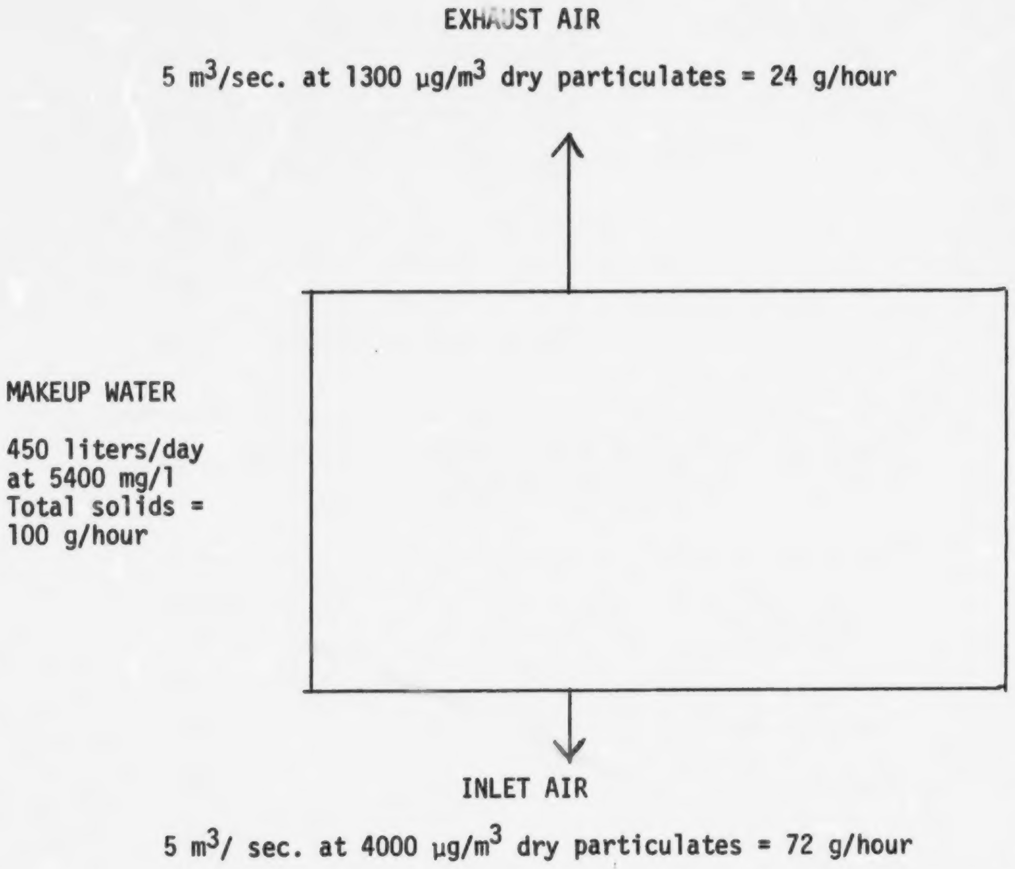

EXHAUST AIR
5 m^3/sec. at 1300 $\mu g/m^3$ dry particulates = 24 g/hour
MAKEUP WATER
450 liters/day
at 5400 mg/l
Total solids =
100 g/hour
INLET AIR
5 m^3/ sec. at 4000 $\mu g/m^3$ dry particulates = 72 g/hour

Figure 23. Poultry house exhaust air particulate reduction by the scrubbing tower during winter operation.

TABLE 23. LIQUID PHASE ANALYSES OF THE SCRUBBER TOWER

Item	Start-up	20 Days	60 Days	80 Days	Typical Make-up Water
Chemical oxygen demand (mg/l)	3900	2300	4400	8500	9000
Total solids (mg/l)	4000	4700	4500	3500	5400
Volatile solids (mg/l)	2400	3500	3200	2000	3800
NH_4^+ (mg/l)	150	75	220	170	75
Total nitrogen (as N) (mg/l)	580	280	500	560	270
Electrical conductivity (micromoho/cm)	2600	2300	2600	3500	2000

SECTION 6

INTRODUCTION: ECONOMICS OF ANAPHAGE PRODUCTION

The art or science of drying poultry manure to produce anaphage is a relatively new concept. The idea of drying manure, as a large scale commercial poultry farm enterprise, has really just been developed in the last 5 to 10 years. Traditionally, poultry manure has been allowed to accumulate under the cages until it could be spread on the fields.

Flegal et al. (1972) showed that there is a direct relationship between the length of storage time of the manure and loss in crude protein value in the resulting anaphage. This resulted in the objective carried out in this project--that manure should be dried as soon as possible after it was produced.

Fixed Costs of Project Additions

The total fixed costs of this system are presented in Table 24. The only costs that are listed are those that were in addition to the normal manure handling and ventilating system. The total cost of $21,259.00 represented an addition to the total house and equipment cost of approximately $4.00 per bird. The dryer and afterburner had an original cost of $12,000.00. This cost was arbitrarily divided into $9,500.00 for the dryer and $2,500.00 for the afterburner.

The depreciation calculations developed in the economics of drying were made for a "life" of 10 years for all items in Table 24. The pumps, fans and dryer probably have an expected life of 5 to 7 years. The rest of the additions have an expected life of 15 to 20 years; thus, a 10 year average was used. The interest and upkeep were both calculated at 10%.

In each drying method presented, calculations of the fixed costs were presented on the basis of one day's cost. This tended to bias the costs somewhat as the longest drying day was calculated at 7.5 hours and the shortest drying day at 1.5 hours.

Drying 75% Moisture Manure

Manure with 75% moisture content is expected in most poultry operations. The costs of drying this manure are presented in Table 25.

The total fixed costs were $16,600.00. This consisted of the equipment necessary to deliver the manure from the gutter cleaner through the dryer, including the afterburner. The fixed cost was $5.50 per day. It took 7 1/2

TABLE 24. FIXED COSTS OF PROJECT ADDITIONS TO THE 5,000 BIRD LAYER HOUSE

Addition	Fixed Costs
Drying tunnel (2 m x 37 m) x $29.20 m^2	$ 2,160.00*
Drying belt and accessories	2,500.00*
Dryer	9,500.00**
Afterburner	2,500.00**
Sump pump and pit	750.00***
Tower and pump	2,269.00***
Recirculating fans and ducts	1,580.00***
	$21,259.00

*If the number of birds is expanded to 10,000 birds, these amounts will have to be doubled.

**These amounts would not change until 25,000 to 30,000 birds are housed in the system (for an 8 hour drying day).

***We estimate that this equipment would handle 2 to 3 times as many birds.

hours to produce the 160 kgs of anaphage.

The total costs of production were $44.47, or 27.8¢ per kg of anaphage. Labor was the highest input cost. Seven and one-half hours @ $3.50 equaled $26.25. The cost of oil was the next highest cost. The dryer used about 44% of the oil, 56.8 liters ($5.11). The afterburner used 71.0 liters ($6.39). The cost of 27.8¢ per kg resulted in a cost of $278.00 per 1,000 kgs ($248.00 per short ton). This cost was high for the producton of anaphage, regardless of its ultimate use.

Drying 67% Moisture Manure

In order to lower the cost of drying the manure, it was stored on the belt, between the gutter cleaner and dryer, for 24 hours. The ventilation air was drawn over the manure and then discharged from the drying tunnel. This method of handling the ventilation air reduced the moisture content of the manure to 67% during the winter months.

The total cost of drying this manure to produce anaphage was $34.07 for daily output of 160 kgs, Table 26. The cost to produce anaphage was 21.3¢ per kg. The largest single cost was labor for the operation of the dryer. The $19.25 labor cost was 57% of the total cost of anaphage production.

The length of time necessary to dry manure during the winter months was 5.5 hours per day. This was 2.0 hours less than the 7.5 hours needed to dry the 75% moisture manure. The 2.0 hours saved also represented a savings of 34.2 liters of oil and $3.38 in energy cost. The energy cost savings was represented by $3.07 oil savings and 0.32¢ saved in electricity for operating the dryer.

The cost of 21.3¢ per kg or $213.00 per 1,000 kgs ($190.00 per short ton) was considered excessive when compared to alternative methods.

Drying 60% Moisture Manure

It was estimated from the results of this trial that if the manure had been put on the belt daily and allowed to be dried by the ventilation air for 24 hours, that the average moisture content of the excreta for the entire year would have been 60%. It was also estimated that it would take 3.5 hours/day to dry the product.

The total cost of producing the anaphage based upon these assumptions was $23.69 for the 160 kgs, Table 27. The cost of producing one kg was 14.8¢. The largest single cost was for labor for the operation of the dryer. The $12.25 labor cost was 51% of the total cost of anaphage production.

The 3.5 hours needed to dry 60% moisture manure represented a savings of 4 hours from the 7.5 hours needed to dry the 75% moisture manure. The 4.0 hours saved represented a savings of 68.2 liters of oil or $6.73 in total energy savings. The $6.73 energy savings were made up of $6.10 oil and 0.63¢ in electricity for operating the dryer.

TABLE 25. COSTS FOR DAILY DRYING FRESH MANURE AT 75% MOISTURE

Item	Amount
Fixed Costs:	
Drying tunnel	$ 2,160.00
Belt and accessories	2,500.00
Dryer	9,500.00
Afterburner	2,500.00
Total fixed costs	$16,600.00
Drying Day- 160 kgs anaphage: Operating costs for 7.5 hours	
Fuel oil for dryer - 56.8 liters @ $.09	$ 5.11
Fuel oil for afterburner - 71.0 liters @ $.09	6.39
Electricity for belt motor	.02
Electricity for dryer	1.20
Labor - 7.5 hours @ $3.50	26.25
Fixed costs ($16,660.00 @ 10 years depr./day)	4.56
Interest	.47
Upkeep	.47
	$44.47

$44.47 ÷ 160 kgs DPW = 27.8¢ per kg or 12.4¢ per lb.
to dry 75% moisture manure

TABLE 26. COSTS FOR DRYING MANURE AFTER 24 HOURS ON THE BELT, OCTOBER THROUGH MAY, MANURE AT 67% MOISTURE

Item	Amount
Fixed Costs:	
Drying tunnel	$ 2,160.00
Belt and accessories	2,500.00
Dryer	9,500.00
Afterburner	2,500.00
Total fixed cost	$16,660.00
Drying Day - 160 kgs anaphage: Operating costs for 5.5 hours	
Fuel oil for dryer - 41.6 liters @ $.09	$ 3.74
Fuel oil for afterburner - 52.0 liters @ $.09	4.68
Electricity belt motor	.02
Electricity for dryer	.88
Labor - 5.5 hours @ $3.50	19.25
Fixed costs ($16,660.00 @ 10 years depr./day)	4.56
Interest	.47
Upkeep	.47
	$34.07

$34.07 ÷ 160 kgs DPW = 21.3¢ per kg or 9.5¢ per lb.
to dry 67% moisture manure

TABLE 27. ESTIMATED AVERAGE COSTS FOR DAILY DRYING OF MANURE AFTER 24 HOURS ON BELT ON A YEAR-ROUND BASIS, MANURE AT 60% MOISTURE*

Item	Amount
Fuel oil for dryer - 26.5 liters @ $.09	$ 2.38
Fuel oil for afterburner - 33.1 liters @ $.09	2.98
Electricity	
1. Belt motor	.02
2. Dryer operation	.56
Labor - 3.5 hours @ $3.50	12.25
Fixed costs ($16,660.00 @ 10 years depr./day)	4.56
Interest	.47
Upkeep	.47
	$23.69
$23.69 ÷ 160 kgs = 14.8¢ per kg or 6.7¢ per lb. to dry 60% moisture manure (estimated as information was not available for the complete year)	

*Costs are for a 3.5-hour drying day - 160 kgs anaphage.

The total cost of $23.69 for 160 kgs was 14.8¢ per kg or $148.00 for 1,000 kgs ($134.00 per short ton).

Drying 55% Moisture Manure

In late December, 1974, 6 fans were added to recirculate the ventilation air in the layer house. An exhaust air "washing" tower was also added. The changes required that the energy and depreciation costs of these items be added to the cost of producing anaphage. However, the need for the afterburner was eliminated by the use of the tower; therefore, the afterburner, energy and depreciation costs were eliminated. A sump pump and pit were also added to the system to pump waste water from the drinking system into the tower tank. The sump pump and pit (energy and depreciation) costs were also added to the anaphage production cost.

The fixed costs of this new (fans plus tower) method of drying were $18,759.00 an increase of $2,099.00 over the fixed cost for the previous methods used.

As a result of the data gathered, it was demonstrated that 55% moisture manure could be produced by this revised method. The estimated cost of anaphage production was $17.25 for the 160 kgs of daily production, Table 28. This resulted in a cost of 10.8¢ per kg. The energy savings were $8.68 which consisted of $9.77 (108.9 liters) savings in oil and $1.09 increased electricity cost.

The total cost of $17.25 for 160 kgs was 10.8¢ per kg or $108.00 for 1,000 kgs ($96.00 per short ton).

Drying 40% Moisture Manure

It was estimated (50% moisture obtained through March; and 30% moisture April through September) that 40% moisture manure would be produced utilizing the technique described in Section 8 for 12 months of operation. The dryer operating time would be only 1.5 hours for the 160 kgs of anaphage produced.

The total cost of producing the 160 kgs of anaphage was $14.66, Table 29. The cost of producing one kg was 9.2¢. The largest cost was labor at $5.25. The next highest cost was $4.20 for depreciation. Labor and depreciation were each approximately 36% of the total cost of production.

The 1.5 hours needed to dry 40% moisture manure represented a savings of 6 hours from the 7.5 hours needed to dry 75% moisture manure. This 6 hours of time represented an energy savings of $9.52 per day. The $9.52 could be broken down to $10.46 savings in oil (116.5 liters) and a 94¢ increase in electrical costs.

The $14.66 cost of producing 160 kgs was 9.2¢ per kg or $92.00 for 1,000 kgs ($84.00 per short ton).

Drying 40% Moisture Manure--With Recommended Changes

If the laying house were remodeled as suggested in the section on recommendations, it is estimated that an average of 40% moisture manure would be produced for the year. The recommended modifications would reduce some of the variable expenses.

The total cost of producing anaphage using this method was estimated to be $12.63 for the 160 kgs, Table 30. A savings of $10.96 resulted in using this method compared to the daily drying of 75% moisture manure.

There was a savings in oil of $10.45 (116.5 liters). There was 51¢ saved in electricity for operating the dryer.

The $12.63 cost of producing 160 kgs was 7.9¢ per kg or $79.00 per 1,000 kgs ($72.00 per short ton).

It should be noted that 800 kgs of manure from 25,000 laying hens in this suggested operation could be dried in a 7.5 hour day. The total cost would be $40.55 or $5.07 per kg, $50.70 per 1,000 kgs ($2.27 per lb. or $45.40 per short ton). If a dryer were available that did not require a

TABLE 28. ESTIMATED COSTS FOR DAILY DRYING JANUARY AND FEBRUARY WITH RECIRCULATING FANS, MANURE AT 55% MOISTURE

Item	Amount
Fixed Costs:	
Drying tunnel	$ 2,160.00
Belt and accessories	2,500.00
Dryer	9,500.00
Tower and pump	2,269.00
Sump pump and pit	750.00
Six (6) recirculating fans and ducts	1,580.00
Total fixed costs	$18,759.00
Drying Day - 160 kgs anaphage: Operating costs for 2.5 hours	
Fuel oil for dryer - 18.9 liters @ $.09	$ 1.70
Electricity	
1. Six (6) recirculating fans	1.44
2. Belt motor	.02
3. Sump pump	.02
4. Tower pump	.43
5. Dryer operation	.40
Labor - 2.5 hours @ $3.50	7.00
Fixed costs ($18,759.00 @ 10 years depr./day)	5.20
Interest	.52
Upkeep	.52
	$17.25

$17.25 ÷ 160 kgs DPW = 10.8¢ per kg or 4.8¢ per lb. to dry 55% moisture manure (estimated 55% moisture manure was not available for the total batch of manure)

TABLE 29. ESTIMATED COSTS FOR DAILY DRYING, 12 MONTHS OPERATION WITH RECIRCULATING FANS, MANURE AT 40% MOISTURE

Item	Amount
Fixed Costs:	
Drying tunnel	$ 2,160.00
Belt and accessories	2,500.00
Dryer	9,500.00
Tower and pump	2,269.00
Sump pump and pit	750.00
Six (6) recirculating fans and ducts	1,580.00
Total Fixed costs	$18,759.00
Drying Day - 160 kgs anaphage: Operating costs for 1.5 hours	
Fuel oil for dryer - 11.3 liters @ $.09	$ 1.02
Electricity	
1. Six (6) recirculating fans	1.44
2. Belt motor	.02
3. Sump pump	.02
4. Tower pump	.43
5. Dryer operation	.24
Labor - 1.5 hours @ $3.50	5.25
Fixed costs ($18,759.00 @ 10 years depr./day)	5.20
Interest	.52
Upkeep	.52
	$14.66
$14.66 ÷ 160 kgs = 9.2¢ kg or 4.2¢ per lb. to dry 40% moisture manure, estimated	

TABLE 30. ESTIMATED COSTS FOR DAILY DRYING, 12 MONTHS OPERATION WITH RECOMMENDED CHANGES, MANURE AT 40% MOISTURE

Item	Amount
Fixed Costs:	
Drying tunnel	$ 2,160.00
Belt and accessories	2,500.00
Dryer	9,500.00
Tower and pump	2,269.00
Sump pump and pit	750.00
Total fixed costs	$17,179.00
Drying Day - 160 kgs: Estimated operating costs for 1.5 hours	
Fuel oil for dryer - 11.3 liters @ $.09	$ 1.02
Electricity	
1. Belt motor	.02
2. Sump pump	.02
3. Tower pump	.43
4. Dryer operation	.24
Labor - 1.5 hours @ $3.50	5.25
Fixed costs ($17,179.00 @ 10 years depr./day)	4.71
Interest	.47
Upkeep	.47
	$12.63
$12.63 ÷ 160 = 7.9¢ per kg or 3.6¢ per lb. to dry 40% moisture manure	

full-time operator, additional savings could be made.

Comparison of Daily Costs

A summary of the costs of alternative methods of producing anaphage discussed in this paper are presented in Table 31. It was interesting to note that the in-house drying techniques produced several positive results, as follows:

1. reduced the manure moisture from 75% to 40%,
2. reduced the machine drying time from 7.5 to 1.5 hours,
3. reduced the fuel oil used for drying from 127.8 to 11.3 liters,
4. reduced the energy cost for drying from $12.67 to $1.71,
5. this produced a savings of up to $10.96 for each 160 kgs of anaphage,
6. this amounted to up to 86.5% of the cost of drying 75% moisture manure,
7. the total cost to produce anaphage declined from 27.8¢ per kg (12.6¢ per lb.) to 7.9¢ per kg (3.6¢ per lb.).

TABLE 31. A COMPARISON OF DAILY COSTS (SOME ESTIMATED) TO PRODUCE ANAPHAGE FROM 75% MOISTURE MANURE AND ALTERNATIVE METHODS IN THE SAME SYSTEM

Item	Manure Moisture %	Hours To Dry	Oil Used Liters	Energy Cost $	Energy Savings $	Energy Savings %	Total Cost To Dry ¢/kg	Total Cost To Dry ¢/lb.
Fresh manure dry every day	75	7.5	127.8	12.67	--	--	27.8	12.6
Winter (Oct.-May) 24 hours on belt	67	5.5	93.6	9.29	3.38	26.6	21.3	9.6
Year-Round 24 hours on belt	60	3.5	59.6	5.94	6.73	53.1	14.8	6.7
Winter (Jan.-Feb.) tower recir. fans, less afterburner	55	2.5	18.9	3.99	8.68	68.5	10.8	4.9
12 mo. recir.fans and tower, less afterburner	40	1.5	11.3	3.15	9.52	75.1	9.2	4.2
Proposed remodeled ventilation system	40	1.5	11.3	1.71	10.96	86.5	7.9	3.6

SECTION 7

INTRODUCTION: UTILIZATION OF POULTRY ANAPHAGE

The complete system for handling and dehydrating poultry excreta that has been previously described in this report has resulted in a by-product of poultry production which must be either disposed of or utilized. The product is dry, granular, can be stored, has a bulk density of about 7.73 kg/ft.^{3} and has an odor similar to ground feed (Surbrook _et al_., 1970).

Poultry anaphage has been used as an ingredient in animal feeds. Research results have indicated that the protein in anaphage is available to the chick, quail and hen (Flegal and Zindel, 1969; Thomas, 1970; Flegal and Dorn, 1971; Nesheim, 1972; Polin and Chee, 1975). Chemical components in anaphage have been reported to be stable (Chang _et al_., 1974) and may be affected by different dehydrators (Chang _et al_., 1975). The importance of a microbiological analysis of anaphage has also been discussed (Chang _et al_., 1975a, 1975b).

In order to determine the feasibility and practicability of recycling poultry anaphage as a feed ingredient, the chemical composition and microbial guidelines for anapahge production should be established. These two parameters, coupled with feeding trials, must be measured and tested to determine the efficacy of poultry anaphage recycling.

MATERIALS AND METHODS

Chemical analysis for moisture, calcium, phosphorus, ash, crude fiber, ether extract, Kjeldahl nitrogen and non-protein nitrogen were done according to A.O.A.C. methods. Triplicate analyses were performed for each anaphage sample and the average of three values is reported. Nineteen anaphage samples were analyzed and the average of 19 values are presented in this report.

For microbiological analysis, anaphage samples were taken directly from the dehydrator aseptically in sterilized glass jars and immediately placed in a refrigerator at the Avian Microbiology Laboratory until microbiological analyses were conducted.

The microbiological analytical method described by Chang _et al_. (1974a) was followed with some modifications. A portion of the sample was aseptically transferred to a tared polyethylene bottle that contained sterile distilled water to form an approximate 1:10 dilution. The exact dilution was calculated from the weight of the water and sample used. At the same time 20-25 grams of the anaphage were placed into each of 3 tared petri dish bottoms. The samples were weighted, placed into a 100°C oven and weighed again after 24 hours to determine percent moisture. The results of the 3 replicates were averaged to give the final moisture content.

The 1:10 dilution of anaphage was placed into a sterile blender jar and emulsified at high speed for 2 minutes. The resulting emulsion was used for both bacterial population counts and bacterial identifications. For the population counts, 1 ml of the emulsion was transferred into 9 ml of sterile distilled water, and a serial ten-fold dilution was carried out through 6 tubes. The procedure was repeated in triplicate.

The Drop-plate method (Miles and Misra, 1938) was used for bacterial population counts. One drop from each dilution was transferred to 2 poured brain-heart infusion plates, using a disposable Pasteur pipette. Each drop was calibrated at 1/35 ml. Again, the procedure was performed in triplicate and one complete set of each dilution series was incubated aerobically while the other was incubated anaerobically. After 24 hours incubation at 37°C, the plates were counted. The first dilution drop that gave definite isolated colonies (generally between 10 and 50 colonies) was counted. The number of colonies was multiplied by the original dilution factor, the inverse of the dilution counted, and 35, and the results of the 3 replicates were averaged to give total aerobic and total anaerobic counts in bacteria per gram sample.

The emulsion used for the population counts was also used for bacterial identification. One ml amounts of the anaphage emulsion were placed into 50 ml of each of the following media: 1) Brain-heart infusion broth (BHI) for general enrichment of all aerobic bacteria, 2) Selenite broth (SB) for enrichment of *Salmonella* spp., 3) Ethylene violet azide (EVA) broth for enrichment of fecal *Streptococcus* spp., 4) EE broth for enrichment of coli-aerogenes group, 5) Rogosa's SL broth (RSL) for enrichment of *Lactobacillus* spp. After 24 hours of incubation at 37°C (all cultures were incubated aerobically except Rogosa's SL), the broth cultures were streaked onto agar plates (BHI broth to BHI agar; SB to Brilliant Green agar; EVA broth to EBA agar; EE broth to EMB agar; RSL broth to RSL agar). After 24 hours incubation at 37°C (RSL agar plates incubated anaerobically) the colonies from these plates were identified morphologically and biochemically.

One ml of the emulsion was also transferred to each of 3 SPS agar pour plates to identify and enumerate sulfite-reducing clostridia. These plates were incubated anaerobically for 48 hours, and if clostridial growth was present, the colonies were counted at this time.

The metabolizable energy of the feed and anaphage samples were determined by two feeding trials using White Leghorn adult females in their first year of production. The first trial started February 12, the second February 22, 1974. The hens were caged singly in wire cages of layer-type batteries kept in an air conditioned room at 22 ±°C. Four hens were assigned to each test diet for 14 days in Experiment #1, and 7 days in Experiment #2. Excreta samples were collected during the last 4 days of each experiment. Diets contained 0.2% chromic oxide for determining the M.E. of samples by the indicator method (Scott *et al.*, 1969). The formulae of the diets used in the E.P.A. project #S-802182-01-2 (prepared by Dr. C. Flegal of the Department of Poultry Science) and those used in the M.E. assays (formulated by Dr. D. Polin) are given in Table 40. The diets and air-dried excreta samples were combusted in a Parr adiabatic bomb calorimeter, moisture was determined on triplicate samples of 2-3 grams dried overnight at 104°C, and chromic oxide was analyzed in feed and excreta by the method of Czarnocki, Sibbald and Evans (1960).

RESULTS

Chemical Analysis

The results of chemical analyses of anaphage are presented in Table 32. For purposes of comparison, the results are presented on a dried weight basis (Table 33).

The crude protein (an average of 19 anaphage samples) on a dried weight basis was 35.64% with a range of 27.46-41.82% (Table 33).

The corrected protein averaged 14.32% with a range of 12.04-21.45%. "Corrected protein" was derived by subtracting the percent of non-protein nitrogen from the percent of Kjeldahl nitrogen and then multiplying by 6.25. The protein level of anaphage from this in-house drying system (crude and corrected) was considered "good" since the protein level in the laying feed was about 16%. The calcium and phosphorus content averaged 8.51% and 2.23%, respectively. Ash, crude fiber and ether extract averaged 25.72%, 11.12% and 2.02%, respectively, Calcium, phosphorus, ash, crude fiber and ether extract were comparable to the results of previously reported anaphage analyses (Chang *et al.*, 1975).

Microbiological Analysis

The microbial count was directly related to the moisture content of the sample (Table 34). There were only 621 aerobic organisms in a gram of anaphage sample when the moisture content was below 1%. An average of 290,286 and 702,602 organisms per gram of anaphage were counted when the sample moisture was 1-4% and 5-10%, respectively. When the moisture of the sample was up to 11-20% or higher than 20%, the microbial counts averaged 16 and 30 millions per gram sample, respectively. Anaerobic count followed the same pattern when compared to the moisture content of the sample (Table 35).

An inverse relation of dehydration temperature and microbial count was apparent from the results (Table 36). Lowering the dehydration temperature resulted in a higher microbial count. The average of aerobic microbial count was decreased from 69,500,000 to 1,739,616 when the dehydration temperature was increased from 177°C to higher than 260°C. It must be noted that the dehydration temperature in the drying chamber was higher than recorded in the table. The dehydration temperatures in Table 36 were merely the setting indicators on this particular dryer. The temperature varies in different locations of the drying chamber and normally is higher than its setting (Surbrook, 1971). It can be noted that the aerobic and the anaerobic counts were significantly reduced when the moisture of the sample was reduced to less than 10% although the dehydration temperature remained at the same setting (Table 36). Furthermore, only 4 groups of bacteria (*Bacillus*, *Clostridium*, *Lactobacillus*, and fecal *Streptococcus*) were recovered when the dehydration temperature was set at 260°C or higher (Table 37).

Metabolizable Energy of Anaphage

The anaphage that was prepared from excreta collected during January, 1974, had its origin from a feed whose formula was the same as the E.P.A. #1 diet fed to one-half of the hens on the project starting in February. The anaphage tested at 10 and 15% in test diets had a determined M.E. value of 1432 Kcal/kg (Table 40). The diet from which the anaphage originated had a determined M.E. of 3008 Kcal/kg. Thus, the hens were 53% efficient in extracting the M.E. energy from the diet. The E.P.A. diet #1, which is essentially the same diet fed in January assayed at an M.E. value of 3051 Kcal/kg, as compared to the nearly alike value of 3008 for the diet fed in January. E.P.A. #2 diet, which contained 10% anaphage for recycling the waste, was formulated to be isocaloric with E.P.A. #1. The data in Table 39 reveals that the M.E. value for these two diets were essentially the same, 3030 vs. 3031 Kcal/kg diet.

The proximate analyses of the diets and anaphage from the E.P.A. experiment are presented in Table 38. The values for the crude protein content of the diets, 16.3-16.6%, are comparable to the calculated analysis of 16.0%. The calcium levels by proximate analysis were 3.69, 3.04 and 3.04% for diets January, 1974, E.P.A. #1 and E.P.A. #2, respectively; the calculated analyses were 3.30% for each diet. The adjustment made for the addition of the anaphage was on target. The phosphorus levels given by the proximate analysis are for total phosphorus. The diet E.P.A. #1 contained 0.752% P as compared to a very similar value of 0.754% in the diet E.P.A. #2 with 10% anaphage. Again, the formulation correctly reflected the adjustment needed for the addition of the anaphage which contained 2.31% P, but whose content was not known until 3 months later when the proximate analysis was completed in a biochemical laboratory back-logged with samples to be done. The point is that estimates on the calcium and phosphorus percentage in the anaphage are valid. However, what is not known is the biological availability of the calcium and phosphorus from anaphage.

An estimate of the total available energy in anaphage was made based upon the percentage of crude protein, ether extract and nitrogen free extract using the energy values of 4.1 Kcal/g, 9.0 Kcal/g and 3.7 Kcal/g, respectively. The anaphage had an estimated energy of 1929 Kcal/g. The determined M.E. of the anaphage at 1432 Kcal/kg revealed that about 74% of its energy was available to the laying hen.

TABLE 32. CHEMICAL COMPONENTS OF ANAPHAGE*

Chemical Components	No. of Sample	Percent	Range (%)
Calcium	19	8.09	6.30 - 10.04
Phosphorus	19	2.06	1.92 - 2.48
Ash	19	24.41	21.66 - 28.25
Crude Fiber	19	10.55	9.45 - 12.76
Ether Extract	19	1.91	1.07 - 2.43
Kjeldahl Nitrogen	19	5.38	3.66 - 6.61
Crude Protein	19	33.94	22.88 - 41.31
Non-Protein Nitrogen	19	3.25	1.88 - 4.14
Corrected Protein	19	13.62	11.13 - 21.19
Moisture	19	4.96	1.05 - 16.67

* As received

TABLE 33. CHEMICAL COMPONENTS OF ANAPHAGE IN DRIED WEIGHT BASIS

Chemical Components	No. of Samples	Percent	Range (%)
Calcium	19	8.51	6.68 - 10.70
Phosphorus	19	2.23	2.07 - 2.57
Ash	19	25.72	22.57 - 29.10
Crude Fiber	19	11.12	9.84 - 12.92
Ether Extract	19	2.02	1.14 - 2.80
Kjeldahl Nitrogen	19	5.81	4.39 - 7.71
Crude Protein	19	35.64	27.46 - 41.82
Non-Protein Nitrogen	19	3.41	2.24 - 4.26
Corrected Protein	19	14.32	12.04 - 21.45

TABLE 34. AEROBIC AND ANAEROBIC MICROBIAL COUNT OF ANAPHAGE RELATIVE TO MOISTURE CONTENT

Microbes	Moisture (%)	Samples Analyzed	Average Microbial Count Per Gram of Anaphage
Aerobic	< 1	2	621
	1-4	8	290,286
	5-10	8	702,602
	11-20	9	16,167,511
	> 20	19	30,246,316
Anaerobic	< 1	2	1,030
	1-4	8	128,857
	5-10	8	667,116
	11-20	9	5,579,183
	> 20	18	15,616,666

TABLE 35. THE EFFECT OF DEHYDRATION TEMPERATURE ON AEROBIC AND ANAEROBIC MICROBIAL COUNTS

Microbes	Dehydration Temperature	Samples Analyzed	Average Microbial Count Per Gram of Anaphage
Aerobic	350°F 177°C	2	69,500,000
	400°F 204°C	8	35,382,000
	450°F 232°C	8	18,392,500
	500°F 260°C	7	17,485,714
	>500°F 260°C	21	1,739,616
Anaerobic	350°F 177°C	2	26,500,000
	400°F 204°C	8	20,625,000
	450°F 232°C	7	9,951,429
	500°F 260°C	7	5,925,713
	>500°F 260°C	21	359,167

TABLE 36. THE EFFECT OF TEMPERATURE AND MOISTURE ON MICROBIAL COUNTS OF ANAPHAGE

Microbes	Dehydration Temperature	Sample Moisture	Average Microbial Count Per Gram of Anaphage
Aerobic	500°F 260°C	> 10%	20,281,666
		< 10%	710,000
	Over 500°F 260°C	> 10%	6,719,520
		< 10%	183,396
Anaerobic	500°F 260°C	> 10%	6,958,333
		< 10%	730,000
	Over 500°F 260°C	> 10%	1,360,530
		< 10%	46,241

TABLE 37. MICROORGANISMS RECOVERED FROM ANAPHAGE SAMPLES

Microorganisms Recovered	Note
Aerobacter aerogenes	
Alkaligenes faecales	
Bacillus spp.	**
Clostridium spp.	**
Corynebacterium spp.	
Enterobacter spp.	
Escherichia coli	*
Lactobacillus spp.	**
Proteus spp.	
Streptococcus spp. (fecal)	**

*Only recovered in high moisture samples.

**Only bacteria recovered when dehydration temperature was 500°F (260°C) or higher.

TABLE 38. PROXIMATE ANALYSES OF ANAPHAGE AND DIETS FROM HOUSE NO. 7 PROJECT OF EPA EXPERIMENT (SUPPLIED BY E. LINDEN, BIOCHEMISTRY DEPARTMENT)

Item	Diet Fed Jan. 74	EPA #1 Fed Feb. 74	EPA #2[a] Fed Feb. 74	Anaphage From Diet Jan. 74
Water	6.78	6.55	6.55	0.45
Nitrogen-Kjeldahl	2.62	2.66	3.10	5.70
Crude protein (Nx6.25)	16.34	16.63	19.38	35.63
Non-protein nitrogen	.54	.55	.85	3.01
Corrected protein	13.00	13.19	14.06	16.81
Ether extract	4.17	4.09	6.63	2.46
Crude fiber	3.44	3.21	4.11	10.83
Ash	9.21	8.26	9.60	23.75
Calcium	3.69	3.04	3.61	8.01
Phosphorus	0.813	0.752	0.754	2.31
Nitrogen-free extract	66.84	67.81	60.28	27.33

[a] Contains 10% anaphage originating from diet fed Jan. 74

TABLE 39. METABOLIZABLE ENERGY VALUE OF DIETS AND ANAPHAGE FED TO WHITE LEGHORN HENS IN THE EPA PROJECT

Sample Tested	Expt. #1[a]	Expt. #2[a]	Mean
Feed collected Jan. 74 (same as EPA #1 diet)	2959	3056	3008 (±69)
Anaphage from feed of Jan. 74			
10% in test diet	----	1483	1483) 1432(±145)
15% in test diet	1546	1269	1408)
Feed - EPA #1 collected Feb. 74	3054	3049	3051 (±3)
Feed - EPA #2 collected Feb. 74			
with 10% anaphage of feed given Jan. 74	3031	3029	3030 (±1)

[a] 4 hens per test diet

TABLE 40. TEST DIETS AND HOUSE NO. 7 DIETS (EPA PROJECT) USED IN M.E. EXPERIMENTS

Ingredient	Parts/1000			
	Diet #1	Diet #1 With Anaphage	EPA #1[a]	EPA #2[a]
Corn - #2 yellow	399	399	689.5	584.5
Soybean meal, 49%	235.5	235.5	165	166
Alfalfa meal, 17%	54	54	20	20
Fat- A-V	--	--	5	34
Corn oil, stabl.	49	49	--	--
Methionine hydroxy analogue	1	1	--	--
Methionine, dl.	--	--	.5	.75
Meat and bone meal, 50%	--	--	30	30
Dicalcium phosphate	22	--	12.5	.25
Limestone	74	57	70	57
Salt	2.5	2.5	2.5	2.5
Choline chloride	1	1	--	--
Layer pre-mix	--	--	5	5
Vitamin mix	5	5	--	--
Mineral mix	5	5	--	--
Anaphage	--	150	--	100
Clintose (glucose)	150	--	--	--
Chromic oxide	2	2	--	--
Sand	--	39	--	--
Total	1000	1000	1000	1000

[a] Formulated by C. Flegal, Department of Poultry Science

Public Health Aspects of Refeeding Animal Manures - as of July 1, 1975, the U.S. Public Health Service, Environmental Protection Agency, Food and Drug Administration, or any other federal agency has not given an official sanction to dry, bag, sell and/or feed dried poultry waste and any animal manure to livestock and/or poultry. In fact, a reprinting of paragraph 500.40 of the Federal Register (page 813804, Vol. 40, No. 60) printed on 27 March 1975, reiterated the 1967 stand of the FDA which specifically states that the FDA has not sanctioned and does not sanction the use of poultry litter as a feed or as a component of feed for animals.

Two states, California and Mississippi, have authorized the use of, and have specifications written for the drying and feeding of animal wastes. CAST Report #41, dated February 19, 1975, prepared by a task force under Dr. P. F. Pratt of the University of California, submitted to the Senate Committee on Agriculture and Forestry (Senator Talmadge, Chairman). This CAST Committee pointed out that "Actions are needed that will promote the beneficial use or increased efficiency of the use of sewage sludges and animal manures. As a society with limited resources, we need to stop thinking in negative terms of waste disposal and instead should think in the positive terms of appropriate use".

The USDA has released a bulletin in March 1974 entitled "Recycling Poultry Waste as Feed -- Will It Pay?" (Agricultural Economic Report No. 254). In summary, this Agricultural Economic Report stated that the processing and feeding of dried layer waste (DLW) is economically feasible for large units of caged layers. The highest net returns are attained by the larger operations when DLW is fed at 12.5% of the ration.

The impact of public health aspects of refeeding Dried Poultry Waste was not a part of this EPA project.

SECTION 8

INTRODUCTION: PSYCHROMETRICS OF SYSTEM

The primary function of ventilation air exchange through a poultry house is to provide fresh air (oxygen) for the birds' metabolic processes and to remove waste gases of carbon dioxide, ammonia and other gases. The quantity of ventilation air exchange needed during cold weather is, however, dependent on the amount of water vapor to be removed, and during hot weather on the amount of waste metabolic heat to be removed; as the metabolic processes require a comparatively small amount of air.

Any housing system that maximizes excreta drying during all seasons must not jeopardize the health of the birds because of an unsatisfactory environment. The ventilation air exchange must be sufficient even during the coldest climatic periods to at least remove the water vapor produced by the respiratory system of the birds. Otherwise, the humidity in the building will continue to rise to the point where it will be detrimental to the health of the birds. During these cold periods when the ventilation air exchange rate is minimal because of the finite amount of heat from the birds, the air has little, if any, capability to absorb additional water from the excreta.

During hot weather, the ventilation air exchange must ideally remove all of the metabolic heat from the birds with a minimum of temperature increase. In other words, if it is 32°C (90°F) outside it is not desirable that it be a number of degrees warmer in the building. One way of keeping the inside temperature the smallest increment of a degree warmer is to provide an infinite quantity of outside air exchange. The other and more practical way is that most or all of the metabolic heat be removed in the form of latent heat in the water vapor. The process of evaporation increases the humidity level of the in-house environmental air some, but not the temperature. Thus, enough summer ventilation air exchange must be provided so as not to allow an increase in the relative humidity above an undesirable level. The house then becomes a large evaporative cooler. The evaporative process must have a source of water and, ideally, this is the excreta which must be dried.

Fresh poultry excreta, like any other wet hydroscopic material, releases moisture until it reaches an equivalent moisture level with the surrounding air. The objective of this phase of the demonstration project was to maximize excreta drying in the poultry house without detrimentally affecting the environment for the birds. All excreta water that can be removed prior to reaching the mechanical dryer, the greater the saving of fossil fuel.

In presenting ventilation design data, Longhouse et al. (1960) relate fecal moisture to feed and water intake. Lampman et al. (1967) used these data to estimate moisture loads for poultry house ventilation systems. Several researchers have reported efforts to capitalize on the drying effect of the ventilation air. Bressler and Bergman (1971) used recirculating fans in the manure pits under cages, then dried the manure pits under cages, then dried the manure with a fuel-fired dryer. Soble (1972) used several devices under caged layers including fans, air jets and screens to enhance the drying.

Oheimb and Longhouse (1974) made manure drying tests in a cage-type laying house test chamber in the effort to minimize odors. Although these reports included data about environmental temperatures and humidity, no specific analyses of these factors were given.

There are many reports giving data as to an optimum environment for laying hens: Ota et al. (1953); Longhouse et al. (1960); Petersen et al. (1960); Mueller (1961); Ota and McNalley (1963); Payne (1966); Lampman et al. (1967); Esmay (1969); Wilson et al. (1972); Structures and Environment Handbook (1973); ASAE Data (1974); and Juston (1974). Some reports involve continously constant temperatures and humidities while others give optimums with diurnal variation. Egg number, egg weight and bird weight are the usually optimized factors. A summary of the results from these reports can best be stated by quoting the recommendations of the Structures and Environment Handbook (1973). These recommendations are: "Air temperature, 45°F (7°C) minimum, 95°F (29°C) maximum; fluctuation, ±5°F (3°C) between 45 and 65°F (7 and 18°C) or +10°F (6°C) between 65 and 85°F (19 and 29°C); and relative humidity 50 to 75%". The literature does not present environmental recommendations for dust. Koon et al. (1963) states that dust production is a function of the environment. They go on to say dust produced is "low in quantity at 50°F (10°C), increases to a high-level plateau at 60 and 70°F (16 and 21°C), and decreases as temperatures approach 100°F (38°C)". Longhouse et al. (1960) states that dust has two bad effects: A vehicle for disease, and it may irritate the internal tissues. Lampman et al. (1967) suggest that dust be controlled by maintaining a relative humidity greater than 50%.

MATERIALS AND METHODS

Primary data for environmental evaluation were the dry and wet bulb environmental air temperatures. The air temperatures were obtained mainly with a mercury-type psychrometer placed in the ventilation air stream.

A fan activated psychrometer was used in the low air velocity location near the center of the house. These data were collected by visual observation, hand-written on a data sheet and subsequently transferred to computer cards. Observations, for the most part, were made every 30 minutes for a 5-hour period twice each week on a regular basis.

The primary data collection equipment involved fan actuated psychrometers using thermister sensors. Each psychrometer consisted of an electric fan and mounting frame with water storage. The fan sucked air through a short duct past the dry bulb and wet bulb thermister. The duct was divided into 2 half-cylinders; 1 for each sensor. The wet bulb was kept wet with a a standard cotton, wet-bulb, wick-type sock. The distilled water storage capacity for each unit was about 1/2 liter and fed a constant water level wick-water supply. The fans were connected to an independent power supply and operated only during data collecting periods. The electrical signal from each sensor was fed to a switching and interpretating unit where the signal was converted from an analog to a digital value. This value was ultimately punched on paper tape. The data acquisition unit has a capacity for 60 temperatures (30 psychrometers), the time of day and wind speeds. Analysis of the data is done by reading the paper tape into a computer and making appropriate calculations and printouts.

Installation, calibration and final satisfactory operation of the thermister psychrometers and associated equipment extended over a longer period than was expected. As a result a multi-point thermocouple strip-chart recorder was also used to collect environmental data. (The paper tape data system was not discarded because wind speed data is needed for the drying analysis.) The thermocouples were installed alongside the thermisters and thus, used the same fan and water supply system. The results from the strip-chart recorder were visually read and punched on computer cards for analysis. All data involved 1 pair (wet and dry bulb) of inlet readings, 1 pair of outlet readings and 1 pair of readings in the center of the house.

A daily log of the operation was kept. This log provided data as to time of manure cleaning, time of drying, a time record of water spills, etc. A continuous record of outside and incoming dry bulb temperature was also made using a liquid/gas remote sensing thermometer connected to a circular recording chart. A similar record of the central in-house temperature was made using a linear chart recorder.

Other data collected were a sampling of dust concentration and air velocity. The dust was collected with a high volume sampler. The sampling was done on May 16, 1973, only. Samples were taken of the outgoing air and of the outside air. Air velocities were taken within the house on May 1, 1973. A hot-wire anemometer was used to measure the velocity of air passing under each cage and over the manure.

The data for analysis involved calculated averages and ranges from the collected raw data of dry bulb and wet bulb temperature. Humidity calculations were made using computer algorithms prepared by Lerew (1972). Dry bulb temperatures were the only averages made directly from input data. The average was made for all data collected for a specific calendar day. For those days involving less than the full 24-hour period, all averages and range values were determined on the basis of the data available.

A humidity ratio was calculated for each dry bulb and wet bulb temperature pair and from these values the averages and ranges were determined for the "day". An average daily relative humidity was also calculated using the average dry-bulb temperature and average humidity ratio.

The monthly summaries presented in Tables 41 and 42 were made from the averages and ranges determined on the daily basis.

RESULTS

As noted from Table 41, the average in-house temperatures were within the recommendations referenced earlier of 7 to 29°C (45 and 85°F) except when the inlet air temperature was greater that the recommended maximum. This was the case for data collected in September, 1973. For this month it is noted that the average inlet temperature was 32.5°C (90.4°F), which accounts for the high temperature of 34.3°C (93.7°F) in the center of the house.

As would be expected, the average in-house temperature is 1 to 7°C (1 to 13°F) higher than the average inlet temperature. This can be noted by comparing the "avg" columns under "inlet" and "center" in Table 41.

A comparison of the average temperatures in the "outlet" and "center" columns of Table 41 will indicate a drop in temperature from the center to outlet for data collected in 1973 but an increase in temperature for data collected in 1974. The drop in temperature might indicate evaporative cooling. This possibility is strengthened by the fact that there was considerable water spillage from the bird waterers in 1973. This problem was corrected in January, 1974, with a new watering system. Much of the water spillage was in the alley; a normally dry surface with no spillage.

Table 42 presents the relative humidity in the same locations and for the same period as the temperatures. It can be noted from this table that the relative humidity did not always fall within the previously referenced recommended range of 50 to 75%. With the exception of data collected in November, the in-house relative humidity was either within the recommended range or greater than the recommended maximum. Results of this type are to be expected where evaporation of moisture is enhanced by design. (The 100% figures for inlet air in February results from omitting water in the inlet psychrometers during freezing weather.)

The results from sampling the air for dust are 8,720 and 11,200 micrograms/m^3 for the outside air and the outlet air, respectively. At the time these data were collected, the outside relative humidity was 89% and the dry bulb temperature was 10°C (51°F).

The average of 5 velocity measurements along the length of the cages and just above the dropping board or floor are: 0.132, 0.127 and 0.838 m/sec. (26, 25 and 165 ft./min.). These figures indicate that of the air passing under the cages in the row next to the inlet about 6% passes under the top cages, about 6% passes under the middle cages and the rest or approximately 88% passes along the floor.

In-House and Belt Drying Potential

During the months of September, October and November, 1973, regular samplings were made of the moisture content of excreta as deposited below the cages in the house and on the belt after 24 hours of drying from ventilation air being exhausted through the tunnel. The daily drying of the excreta in the poultry house remained fairly constant from the 80% voided

TABLE 41. LAYING HOUSE ENVIRONMENT USING VENTILATING AIR TO DRY MANURE: TEMPERATURE AT THE DESIGNATED LOCATIONS (TOP FIGURES DEGREES CELCIUS; BOTTOM FIGURES DEGREES FAHRENHEIT)

		Inlet			Center			Outlet		
Mo.	Yr.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
8	73	18.	28.	22.2	21.	29.	24.3	19.	28.	22.9
		65.	82.	71.9	69.	84.	75.7	67.	83.	73.2
9	73	31.	34.	32.5	33.	35.	34.3	30.	32.	31.6
		88.	93.	90.4	91.	95.	93.7	87.	90.	88.8
10	73	7.	24.	14.2	11.	24.	17.4	11.	25.	16.7
		45.	75.	57.6	52.	75.	63.2	52.	77.	62.0
11	73	1.	8.	5.1	10.	13.	11.6	5.	12.	8.8
		33.	47.	41.2	50.	56.	52.9	41.	53.	47.9
2	74	-10.	13.	3.1	6.	15.	10.2	10.	24.	16.3
		14.	55.	37.5	42.	59.	50.3	50.	75.	61.3
5	74	9.	18.	10.9	12.	18.	13.0	17.	21.	17.8
		49.	65.	51.6	54.	65.	55.4	62.	71.	64.1
6	74	12.	28.	17.8	14.	28.	19.2	17.	30.	21.9
		53.	82.	64.1	58.	82.	66.5	62.	85.	71.3
8	74	3.	32.	23.2	16.	31.	24.5	13.	34.	24.8
		37.	90.	73.7	60.	87.	76.1	56.	93.	76.7

TABLE 42. LAYING HOUSE ENVIRONMENT USING VENTILATING AIR TO DRY MANURE: RELATIVE HUMIDITY AT THE DESIGNATED LOCATION (AVERAGE DAILY, PERCENT)

		Inlet		Center		Outlet	
Mo.	Yr.	Min.	Max.	Min.	Max.	Min.	Max.
8	73	58.	79.	53.	77.	58.	78.
9	73	45.	75.	43.	50.	50.	55.
10	73	53.	95.	55.	84.	48.	80.
11	73	87.	88.	41.	57.	56.	70.
2	74	85.	100.	70.	82.	69.	89.
5	74	83.	92.	74.	81.	72.	92.
6	74	75.	86.	77.	100.	69.	89.
8	74	62.	92.	89.	98.	70.	91.

moisture content level to about 72% wet basis (all moisture content percentages given in this paper are wet basis). However, the drying of the excreta on the belt decreased each month from September through November. In September the moisture content dropped by 9% during 24 hours on the belt, in October 7% and in November 3%. This trend is accounted for by the prevailing weather conditions of East Lansing, Michigan. Columns 1 and 2 of Table 14 give average monthly temperatures and humidities for September, October and November. The average in-house environmental conditions are shown by columns 5 and 6. The average number of pounds of water removed daily from the excreta of 5,000 hens from in-house and on-the-belt by the ventilation air is shown by columns 9 and 10 of Table 14. Also, the ventilation air must remove all of the latent heat produced by the laying hens. This is shown by column 11 of Table 14 to be an additional 654.5 to 763.6 kg per day for 5,000 hens.

A gross psychrometric analysis for the 3 months of September, October and November of 1973 is presented in Table 14. It is interesting to note that the required ventilation rate to remove the above indicated amount of water from the house under the average climatic and environmental conditions was slightly over .085 M^3 per hen in September and October and down to nearly .028 M^3 in November (column 19). The house heat necessary for maintaining the ventilation and house condition was quite close to handbook data on heat produced (see column 21 of Table 14).

Ventilation Fan Operation

The demonstration poultry house was equipped with 5 ventilation exhaust fans. Four were .915 M fans powered by 1 hp motors and with rated capacities of 283.2 M^3 each. The fifth fan was an .457 M, 1/3 hp which ran all of the time. Separate electrical watt-hour meters were used on the small fan, the large fans numbered 1 and 2 and the large fans numbered 3 and 4.

The summarized electrical energy utilization by ventilation fans is shown by Table 43 and Figure 24. The graphical presentation show that the operation of the large fans correlates directly with the average monthly climatic temperatures in lower central Michigan indicated by the broken lines. The longer broken line is an average of weather bureau data over many years while the shorter broken line represents the average monthly temperatures during the actual months of the project.

The total kilowatt hour per day consumed by all 4 large fans is the best indication of total fan operation and thus, ventilation air exchange.

It will be noted for April and May that the total energy consumed by the 4 fans conforms closely with a temperature variation in 1974 when April was warmer than usual and May somewhat cooler. The greater amount of fan operation in August as compared to July does not seem to be indicated by the average month temperature data.

Based upon manufacturers rated air delivery capabilities of the fans and energy utilization, the average ventilation air exchange per bird was calculated and is shown by one column of Table 43. These ventilation rates are somewhat higher than what has been normally recommended in the past, and also higher than thought possible in poultry houses with only the bird metabolic heat for environmental control. The plan of operation for this house was, of course, to maximize excreta drying by maximizing air movement without jeopardizing an optimum environment. The higher ventilation air exchange rates are somewhat due to the higher density of birds in the triple-deck poultry house. On the other hand, the actual ventilation air exchange through the house may be somewhat less than the rated outputs of the fans.

Electrical energy consumption data also provides an indication of operational costs. For example, during August, the month of maximum fan operation, an average of about 120 kilowatt hours per day were consumed by all 5 fans. If a kilowatt hour cost of 3¢ is assumed, the fans would cost $3.60 per day to operate. The cost dropped down to about $.60 per day during the coldest winter months of January and February.

The energy requirement for a rated output of 2.83 M^3 was about 130 watts per hour. This can be reduced on down to the electrical energy required to provide 28.3 M^3 of air exchange of about 2 watts. Thus, during the month of August for a cost of $3.60 per day the fans delivered about 1,699,000 M^3 of ventilation air exchange each day.

A Simulation for Drying Poultry Excreta with Ventilation Air

A simulation is an iterative process in which a series of appropriate calculations are made to determine an estimate of some unknown variable or variables in the system. The iterative process usually implies a dynamic simulation, i.e., the simulation calculations are repeated as time (or another independent variable) advances at a regular interval. Although such

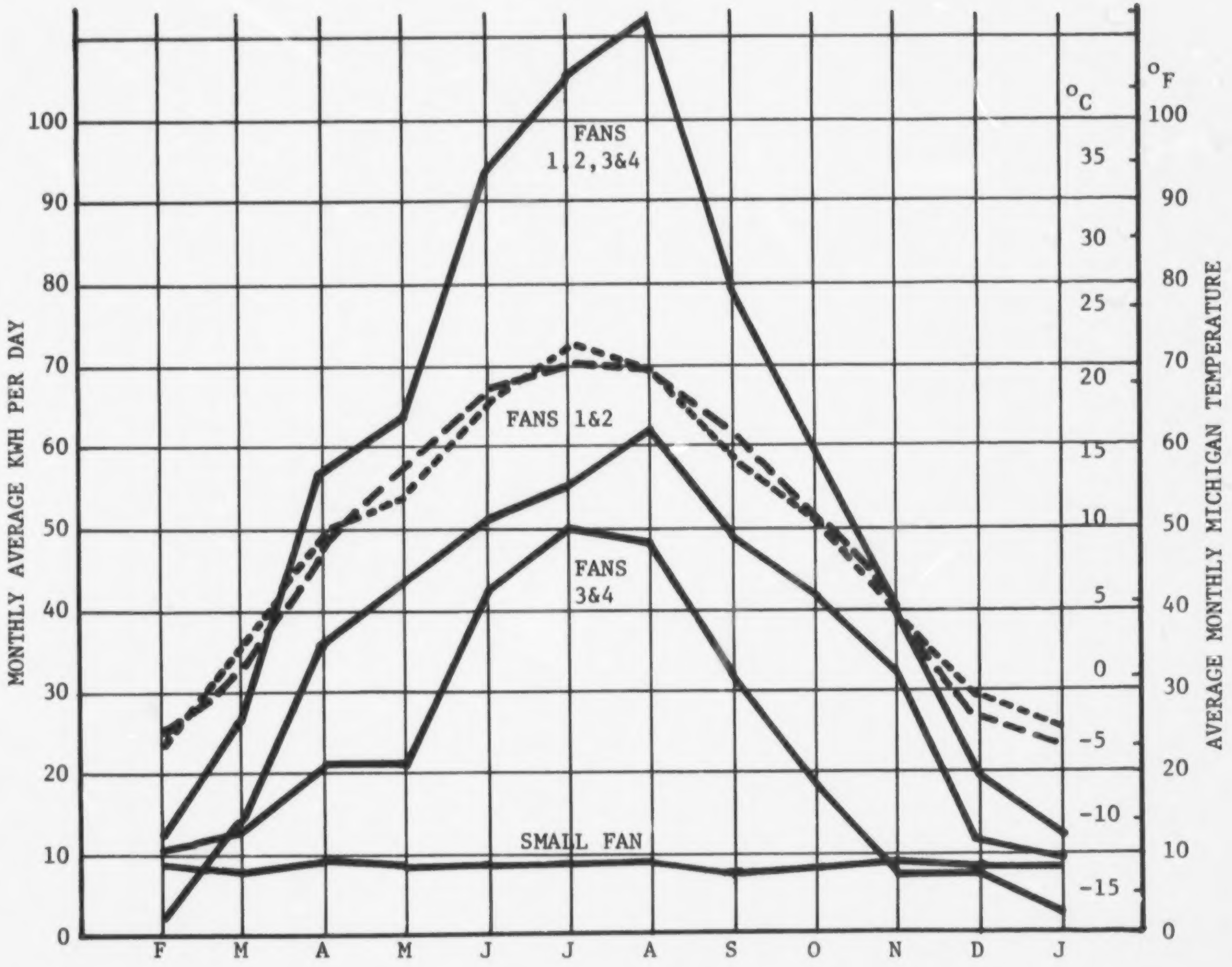


Figure 24. Electrical energy consumption

TABLE 43. ELECTRICAL ENERGY UTILIZED BY FANS AND VENTILATION AIR EXCHANGE PER FAN

Month Of Year	KWH/Day 18' Fan (.457M)	KWH/Day Fans 1 & 2	KWH/Day Fans 3 & 4	KWH/Day Fans (1, 2, 3 & 4)	M^3 /Hen
Feb. 74	8.75	1.2	10.3	11.5	.0364
Mar. 74	7.95	13.9	12.7	26.6	.0644
Apr. 74	8.88	35.1	21.0	56.1	.1148
May 74	8.25	43.1	20.6	63.7	.1288
Jun. 74	8.95	50.8	42.5	93.3	.1820
Jul. 74	8.90	54.8	50.2	105.0	.2044
Aug. 74	8.70	62.2	49.2	111.4	.2156
Sep. 74	7.68	48.1	32.2	80.3	.1596
Oct. 74	8.00	42.0	18.3	60.3	.1260
Nov. 74	8.62	31.9	7.1	19.1	.0504
Dec. 74	8.14	12.0	7.1	19.1	.0504
Jan. 75	8.45	9.8	2.3	12.1	.0364

calculations can be made by the analyst with a calculator, they are best made with a computer.

The dynamic simulation discussed here involves the egg production system of the demonstration project. The primary measure of effectiveness of the system is the amount of water removed from the excreta by the ventilating air. The effect of moisture removal is also expressed as the excreta moisture content.

In preparing the simulation certain parameters must be known or assumed. For the system discussed here these are: a) outside air psychrometrics, b) moisture content and quantity of excreted material, c) the physical parameters of the building (size, insulation, lighting, etc.), d) ventilation system limits and operating conditions, e) surface area of waterers, f) number of hens, and g) laying rate.

The first operation for starting the simulation is to initialize or numerically define the fixed parameters mentioned above. This is followed by determining the appropriate psychrometric values for the outside air at regular time intervals for a 24-hour period. (The selected time interval might be one-half hour, for example.) Another initial factor that must be determined is the coldest outside temperature at which the inside optimum (or present temperature) can be maintained. Next, determine the expected daily amount of excreta to be produced. At this point, start the iterative process and determine the amount of excreta produced up to the time of the specific iteration. The next step is to specify whether it is "daytime" (lights on) or "nighttime" (lights off) for the specific iteration so the correct metabolic heat can be determined.

The above operations are followed by 2 questions of logic involving the outside dry bulb temperature. With the first the outside dry bulb is compared with the predetermined optimum inside temperature. If the outside temperature is higher, an inside higher temperature must be calculated. If the outside temperature is lower, the second question of logic determines if the outside temperature is less than a predetermined outside minimum. When the outside temperature is less than this minimum an inside lower temperature must be calculated. When the outside temperature falls between these values the inside temperature is set at the optimum (predetermined) value. Each of these branches in the simulation requires a different calculation sequence and will be discussed separately; first, the sequence with the inside temperature at the optimum value.

Maintaining the optimum or present inside temperature is done by varying the ventilation rate and this rate must be determined for each iteration. Since the rate is determined by a trial and error convergence, an initial guess ventilation rate is made. The next step is to determine the ventilation rate.

When the outside temperature is higher than optimum (summer conditions) the ventilation rate is at the maximum and the inside temperature must be determined. Again, a trial and error convergence technique is used. This requires an initial guess for the inside temperature and subsequent determination of the inside temperature.

When the outside temperature is less than the coldest outside temperature that will maintain the present inside temperature, the ventilation rate is at the minimum value. With this ventilation rate (winter conditions) a trial and error convergence is used to find the inside temperature.

With the appropriate inside temperature and ventilation rate the next step is to determine the quantity of water evaporated from the manure and waterers for the iteration interval. These values are then added to like quantities from previous iterations. The moisture content of the excreta at the end of the iteration is the next computational step. The last regular step of the iteration is to file or store the results of the calculations.

At the end of the iteration a check is made to see if the time is midnight. If it is, weather data for the next day is read and additional psychrometric data for the outside air is calculated for use in later iterations. If appropriate, the process is repeated for the next iteration. When the iterative process is complete, results from the moisture content and water removed calculations are tabulated on a printout.

Subprogram Algorithms

In the simulation description above there are numerous references to "determine" and "calculate". Each one of these references implies there is some algorithm to find if the desired quantity is contained in a subprogram. Many of the subprograms (or subroutines) suitable for this simulation have been developed by others and will be noted by reference only. Other subroutines have been developed specifically for this simulation and will be discussed here.

Perhaps, the most universally useful group of subroutines is the package developed by Bakker-Arkema and Lerew (1972). This group of subroutines calculates the psychrometric properties of air-vapor mixtures for all values and combinations ordinarily determined by a psychrometric chart. Another group of subroutines was developed by Phillips (1970). This group calculates the heat loss or gain through the walls, ceiling and floor of a laying house. It also includes subroutines to determine the heat generated by electric lights and the metabolic heat and respiration from the laying hens. Another useful routine is reported by Llewellyn (1965). Its function is the same as finding and interpolating paired data from a table.

Several specific algorithms are needed for this simulation. For the most part, the data and relationships are found in the literature. A discussion of each subprogram which involves 1 or more algorithms follows. For reasons of continuity, the same 6 or less character names used in the simulation will be used here for identification. The discussion will be in alphabetic order according to this name. Equations, only, will be presented.

AMC

The purpose of this routine is to determine a moisture content. The definition of wet-basis moisture content is used, i.e., MC = (water weight)/(material with water weight).

DRYHET

The purpose of this routine is to calculate the heat required to evaporate the water from manure and waterers. In doing this, however, it is also necessary to know the drying rate and the quantity of water evaporated.

The latter two quantities are calculated by other routines but are made available to the main program through this subroutine. The unique equation of this routine is: Heat of evaporation = (weight of water evaporated) x (latent heat).

DRYRAT

The purpose of this subroutine is to determine the drying rate of the manure. The algorithm used here is specific to poultry manure. The basic equation for the drying rate was obtained from Perry et al. (1963), (p. 15-35). Data for obtaining the specific constants for poultry manure were obtained from Wells (1972). The drying rate equation is

$$dw/do = h_t A \ (t - t's) \ \lambda \text{ or}$$
$$= kgA \ (ps - p)$$

where:

dw/do = drying rate LB H_2O/hour

h_t = total heat transfer coeffient BTU/(hour) (ft.^{2}) (^oF)

A = Area, ft.^{2}

t = dry bulb temperature, ^oF

$t's$ = temperature of evaporationg surface, ^oF

λ = latent heat of evaporation at t's, BTU/lb.

hg = mass transfer coefficient lb./(hour) (ft.^{2}) (ATM)

ps = vapor pressure of water at surface temperature, ATM

p = partial pressure of water in air, ATM

A reasonable assumption which will simplify calculations is that all heat transfer is by convection and the drying surface is a flat plate. Perry, et al. (1963) state that $h_t = h_c$, the convective heat transfer coefficient, when heat is transferred by convection only. Their equation for convective heat transfer is

$$h_c = \alpha \ G^N / D_c^m$$

where:

hc = convective heat transfer coefficient BTU/(hour) (ft.^{2}) (^oF)

G = mass velocity, lb./(hour) (ft.^{2})

D_c = a characteristic dimension, ft.

d, m, n = constants

The value, G, can be represented by the weight rate of flow divided by the cross-sectional area. For a flat plate, D_c, can be the length of drying solid over which the air-stream passes. From the discussion and examples used by Perry et al. (1963) and by Wells (1972), it is apparent that $m = 1-n$ and that these constants along with α are specific to a material and drying conditions. Using data supplied by Wells (1972), values for these constants have been determined: $n = 0.4029$ and $\alpha = 0.6344$. Perry et al. (1973) in their discussion of drying note that drying of a material occurs in 2 modes: the constant-rate mode and the falling-rate mode or period. The falling-rate period only occurs at the end of the drying process, i.e., when the moisture content of the material is low. The manure in the laying house will have a high moisture content and thus drying will be in the constant-rate period.

DRYSRF

The purpose of this subroutine is to find the surface area of the waterers, the drying manure and their sum. Determining the surface area of the waterers is quite straight-forward; the area equals the width times the total length. The surface area of the manure is obtained by an estimate.

From personal observation a poultry manure dropping takes the general shape of a hemisphere. Some random measurements of these hemispheres indicate a reasonable average diameter is 2 cms. The specific gravity of poultry manure as given by Wells (1972) is 1.005, thus the weight (pounds) per dropping is 0.004616 and the surface area (square feet) per dropping is 0.0067573. With these constants and a given weight of manure, the manure surface area (square feet) can be calculated as 1.43639 times the manure weight (pounds).

EVPWTR

The purpose of this subroutine is to calculate the water removed from the waterers, the manure and the sum of these quantities. These calculations are straight-forward when the drying rate is known, i.e., the water removed (pounds per hour) is equal to the drying rate (pounds per hour - square foot) times the surface area (square feet). The drying rate is determined in another subroutine (DRYRAT).

EXCRAT

The purpose of this subroutine is to calculate the daily manure production. Holtman *et al*. (1972) related excreta rate to egg production with a factor of 0.4 pounds of excreta per egg-day. The daily amount of manure (pounds) is then the product of this factor and the number of eggs produced on a given day.

TEMGES

The purpose of this subroutine is to calculate the heat flow imbalance in a heat balance equation. The heat balance equation is an algebraic sum, i.e., net imbalance = heat from electric lights; + sensible heat from laying hens; + latent heat from laying hens; + heat transfer through the ceiling; + heat transfer through the walls; + heat transfer through the floor; + heat transferred with the ventilating air; + heat transferred to evaporate moisture. All values have units of BTU per hour.

TEMPIN

The purpose of this subroutine is to determine the inside temperature of the laying house. The temperature is determined by a Newtonian convergence similar to that used by Phillips (1970). The convergence is based on Newton's method (Smith et al., 1947) for finding roots of a function, f(X). An estimate of a root, x_1 is made. By evaluating the function at x_1, the equation for the tangent-line through x_1 can be written as

$$y - f(x_1) = f^1(x_1)(x - x_1)$$

when:

$$y = 0$$

$$x = x_1 - f(x_1)/f^1(x_1)$$

where:

x = an estimate of the root

The process can be repeated until an acceptable small error is obtained.

Mathematical differentiation cannot be done with a digital computer but an approximation is possible. The convergence for this subroutine can be found as follows:

Let Q = the solution to the function

When T_o = the estimated temperature inside the laying house for evaluation of f (t).

Now let Q_p = the solution to the same function as above

But with $T_p = T_o - a$

And Q_m = the solution to the same function as above.

But with $T_m = T_o - a$

Where a = some constant increment of temperature, usually 1.

Differentiate the function by difference, i.e.

$$Q^1 = (Q_p - Q_m)/za$$

The new estimate of temperature is $T_1 = T_o$. It should be checked for an acceptable error to determine if the process should be repeated or the estimated value accepted as the root, i.e., the inside temperature of the laying house.

TIMPIN

The purpose of this subroutine is to determine the minimum outside temperature for which it is possible to maintain the optimum or predetermined inside temperature. This outside temperature is determined by a

Newtonian convergence. The method is discussed elsewhere (see TEMPIN) and need not be repeated here except to note that the same function for heat balance is used but the independent variable is the outside temperature with all other variables including the inside temperature remaining constant.

VENRAT

The purpose of this subroutine is to determine the ventilation rate through the laying house that will maintain the optimum or preset temperature. This rate is determined by a Newtonian convergence. The method is discussed elsewhere (see TEMPIN) and need not be repeated here except to note that the same function for the heat balance is used but the independent variable is the ventilation rate with all other variables including the inside temperature remaining constant.

WETHER

The purpose of this subroutine is to develop an estimate of the weather conditions at the time of each iteration. The basic data for this development is the U.S. Weather Service records. The appropriate available information is the average dry-bulb temperature for a day, the range of this temperature and the dewpoint temperature for the day.

These, of course, could be from historical data or estimates for future dates.

Phillips (1970) gives equations which estimate the temperature function as it varies with time through a day. His function is as follows: for

$o<t\leq 6$

$$T = T_m+R_2\ (1+\cos((t+18)/30\pi)),$$

for $6<t\leq 15$

$$T = T_m+R_2\ (1+\cos\ ((t-12)/18)\pi)),$$

for $15<t\leq 24$

$$T = T_m+R_2\ (1+\cos((t-30)/30)\pi)),$$

where T = outside dry bulb temperature, ^{o}F,

T_m= minimum outside dry bulb temperature,

R_2= one-half outside temperature range, and

t = time, hours per 24-hour clock.

He also states the dewpoint temperature can be considered constant for the day.

SECTION 9

ENGINEERING CRITERIA FOR POULTRY EXCRETA DEHYDRATION SYSTEMS

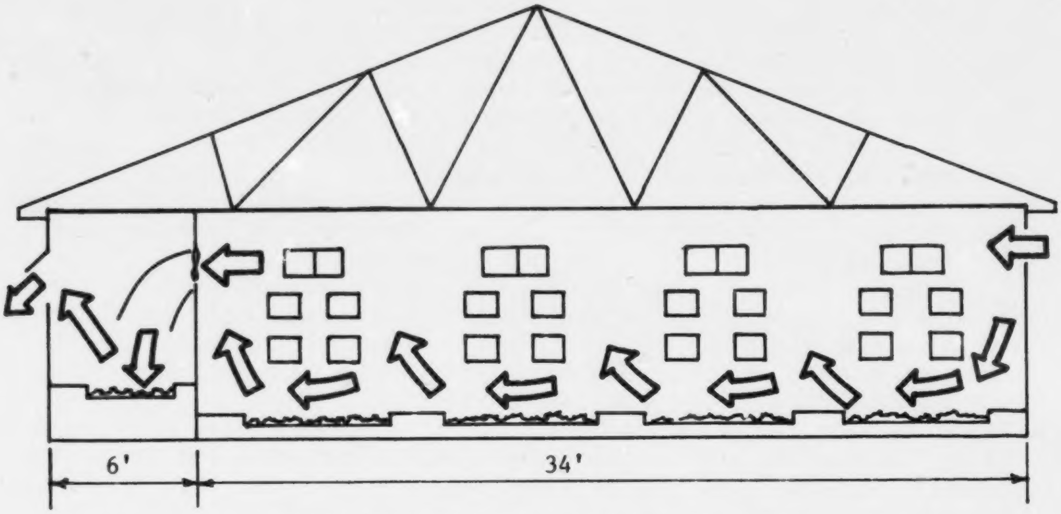
SUMMARY

1. Maximize daily air drying of droppings as deposited in the dropping pits and on dropping boards during all seasons. (Clean pits daily).
    - A. Direct ventilation-air flow across the surface of the daily accumulated excreta.
        - 1) Inlet ventilation air should be directed downward from the slot inlet to the dropping pit level and then across the pits to the exhaust fans during both summer and winter operation.
    - B. Provide 8 cfm (13.6 m^3/hour)/bird ventilation air exchange capacity for summer operation and controls to reduce this to the 0.5 to 1 cfm (1 to 2 m^3/hour)/hen range during cold weather.
2. Maximize the cold weather ventilation air exchange in the following ways:
    - A. Insulate the house well to conserve bird heat for warming ventilation air.
        - 1) Sidewalls R=12. [3.5 in. (8.75 cm) blanket insulation or equivalent]
        - 2) Ceiling R = 20. (Horizontal ceiling is recommended)
        - 3) Foundations R = 8. [2 in. (5 cm) polystyrene board outside of foundation wall or equivalent]
    - B. Increase density of birds in the house to an equivalent floor area of 0.3 to 0.4 ft.^{2}/hen (0.03 to 0.037 m^2/hen).
        - 1) This means a triple-deck cage system or some equivalent floor area per hen.
3. Water leakage into the dropping pits from the cage waterers must be eliminated as there is no way that additional amounts of water can be economically removed by dehydration. The system can cope with normally produced excreta water, but not with overflowing and/or leaking cage waterers.
    - A. One way to assure this is provide a small trough under the individual cage waterers to carry away overflow and leakage water. A large trough system of watering will also serve the same purpose of eliminating leakage.
4. Install a 30 inch (75 cm) wide belt in a 6 ft. (1.8 m) wide tunnel the full length of the poultry house.
    - A. The daily excreta production is moved onto the belt where it is subjected to another day of air drying from the exhaust ventilation fans (see Figures 25 and 26).
    - B. After this second day of drying (the first day is in the poultry house) the moisture content of the excreta should be reduced to the 50% (wet basis) level during both summer and winter seasons. This

means that three-fourths of the original excreta water has been removed. Only one-fourth of the water is then left for removal with a heated air dryer in reducing the moisture content to (approximately) 10%. The 50% w.b. excreta could also be moved directly to the land as fertilizer without fear of air or water pollution.

   C. The excreta drying belt in the tunnel should be 30 in. (75 cm) wide for a poultry house having 96 hens/ft. (30 cm) of house length. [This would be a 4-row, triple-deck, cage system with four hens per 12 in. (30 cm) cage]. The excreta on the belt with daily cleaning would be approximately 2 in. (5 cm) deep.
   D. The excreta drying belt should be an endless polyvinyl belt powered to run in either direction. A cross conveyor will load the belt from the pit scrapers at one end of the house.
   E. A means should be provided to intercept the excreta directly from the cross conveyor for direct removal in case the belt malfunctions. Also from the other end of the belt, in case it delivers directly into a dryer, an alternate means of unloading the belt must be provided in case the dryer malfunctions.

5. The 10,000 cfm (17,000 m^3/hour) exhaust fans should be installed every 14 ft. (4.25 m) in the partition wall between the house and the drying tunnel. Each one should be provided with a flared hood that will distribute the exhausted air over a 7 ft. (2.1 m) length of belt. (See Figure 2). Sometime during the daily belt drying period the belt should be moved ahead 8 ft. (2.4 m) for better drying of the in-between-fan sections of excreta on the belt.
   A. Provide for additional air turbulence of ventilation air over excreta on the belt during cold weather when ventilation air exchange may only be 1 cfm (2 m^3/hour)/hen. This means that one out of every 8 fans would be operating in order to provide the necessary ventilation air.
      1) Some of the non-operating fans should be adapted to just recirculate air onto the belt excreta. This may be done by placing a specially shaped housing over the inlet side of the fan that brings air from the drying tunnel through openings on either side of the fan.
      2) Enough fans should be operated as air recirculators to bring the excreta to 50% w.b. during cold weather.
6. The drying tunnel must be insulated according to the same specifications for the laying house.
   A. Ventilation air exhausted into the tunnel is outletted through a gravity type continuous slot outlet that is a minimum of one foot (1/3 m) wide.
7. The heated air dryer should have the capacity of drying the daily production of excreta for the house from 50% to 10% w.b. in from 6 to 8 hours/day. For a 400 foot (120 m) long building, housing 38,000 laying hens, the daily water removal for the dryer would be about 2,000 lb. (900 kg) or from 260 lb. (118 kg) to 330 lb. (150 kg)/hour this is a small dryer. Possibly one or two houses might deliver to the same dryer and the dryer capacity doubled or tripled accordingly.



CROSS SECTION VIEW - 40' X 400' HOUSE

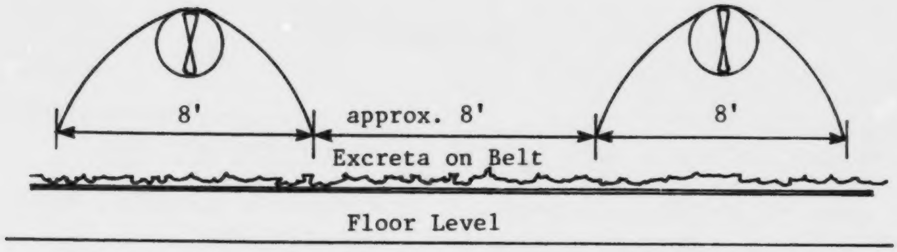
SPECIFICATIONS:

4 hens/12" x 16" cage
96 hens/ft of house length
768 cfm/ft of house length
A 10,000 cfm fan about every 14 ft
0.354 ft^2 floor area/hen
400 ft house = 38,400 hens

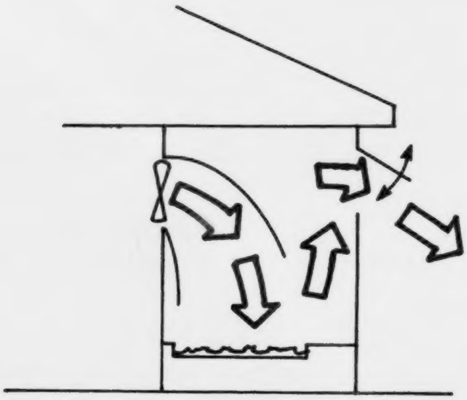
EXCRETA:

.054 lb/day/hen dry matter
5.18 lb/day/ft of house length
.027 lb/day/hen wet at 80% w.b.
25.9 lb/day/ft wet at 80% w.b.
0.16 lb/day/hen H_2O out 80% 50%
15.4 lb/day/ft H_2O out 80% 50%
0.052 lb/day/hen H_2O out 50% 5%
5.0 lb/day/ft H_2O out 50% 5%
at 60 lb/ft^3 at 80%, vol/ft = 0.433 ft^3
depth on 30" belt = 2"

Figure 25. Ventilation air flow pattern for maximizing excreta drying.



WALL ELEVATION IN DRYING TUNNEL



CROSS SECTION OF DRYING TUNNEL

Figure 26. View of fan air distribution for maximizing excreta drying.

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APPENDICES

APPENDIX A. DRIED POULTRY WASTE AS A PROTEIN SOURCE FOR FEEDLOT CATTLE

By

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INTRODUCTION

Waste disposal in animal agriculture has become not only a management problem, but also an environmental pollution concern to people associated with the animal industries. The poultry industry tried to dry poultry waste to abate the waste disposal problem. Due to the high protein content of fresh poultry waste (as high as 50% CP), research was conducted using dried poultry waste (DPW) as a protein supplement for chickens and cattle. However, data on recycling DPW through cattle is limited.

OBJECTIVE

The objective of this study was to determine the value of DPW as a supplemental protein source for feedlot cattle.

PROCEDURE

The Poultry Science Department, Michigan State University, provided DPW from caged layers. Fresh excreta containing 25% DM was dried to a product of 90% DM. The dryer consists of five internal, inclined surfaces that shake in a horizontal action, causing the material to slide down the surfaces during the drying process. A hammer mill, used for mixing and pulverizing, is located at the lower end of the top inclined surface. A stainless steel plate, with either .635 cm or .9525 cm holes, acts as a screen to limit maximum particle size. To complete the drying process, the material must pass through the holes in the screening plate. The machine operates at a temperature ranging from 93.3°C to 592.5°C and has a fresh to dried poultry excreta production rate of 1545 kg/hour. The DPW in this experiment had a particle size varying between .0397 cm to .3175 cm, contained 17% crude protein, and had a slight odor.

Five rations balanced to 12% crude protein (Table 1-A) were compared. DPW was combined with either soy or urea, 1/2 of the required supplemental protein was derived from DPW and the other 1/2 derived from soy or urea. All rations were mixed in a horizontal mixer before feeding and all cattle were full fed twice daily.

Yearling steers used in the experiment averaged approximately 690 lb. in weight and originated from the Beef Cattle Forage Research Station, Lake City, Michigan and the Virginia Feeder Calf Sale. The trial began on May 7, 1970 and steers were lotted randomly according to weight and origin. All steers were implanted with 36 mg diethylstilbestrol and given an intramuscular injection of 5,000,000 I.U. of Vitamin A, 500,000 I.U. Vitamin D_2 and 500 I.U. of Vitamin E.

At the beginning and end of the experiments, cattle were individually weighed on two successive days and the average of the two days was used as initial and final weight. During the course of the experiment, all lots of cattle were group weighed every 28 days.

At the end of the experiment and immediately following the final weight, all cattle were trucked 161 kms, left to stand over night and slaughtered the next morning.

After 48 hours in the cooler, carcasses were ribbed, graded and carcass measurements taken. Kidney, heart and pelvic fat was estimated by the federal grader and fat and lean tracings were made of the 13th rib for accuracy in determining cutability grade, fat thickness and rib eye area.

RESULTS

Complete results for all treatment groups are shown in Table 2-A. The source of protein has a large and highly significant effect on average daily gain. Average daily gain for the soy supplemented group (1.52 kg) was significantly greater than the group supplemented with DPW (1.25 kg), 1/2 DPW - 1/2 urea (1.38 kg) ($P<.01$, $P<05$, $P<.05$, respectively). However, this was not significantly greater than the urea supplemented group (1.41 kg). No significant differences in average daily gain occurred between the groups supplemented with urea, 1/2 DPW - 1/2 soy or 1/2 DPW - 1/2 urea.

Feed effeciency was superior for the soy supplemented group followed by urea, 1/2 DPW - 1/2 urea, 1/2 DPW - 1/2 soy and DPW, (3.16, 3.29, 3.32, 3.70, 4.74 kg of 35% DM per pound of gain, respectively).

The feed cost per cwt of gain was lowest for the soy supplemented group followed by urea, 1/2 DPW - 1/2 urea supplemented group ($14.58) followed closely by urea ($15.03) and soy ($15.31) supplemented groups. The dried poultry waste ($18.87) and the 1/2 DPW - 1/2 soy ($16.84) supplemented groups had the highest cost per cwt of gain.

Steers refused to consume the DPW portion of the ration. This partially explains the poor feed efficiency and performance of the DPW and 1/2 DPW 1/2 soy supplemented groups. The steers sorted the shelled corn and corn silage from the well mixed ration leaving almost as much dry poultry waste as had been presented. The carcass evaluation data showed no significant difference ($P<.05$) when the groups were compared. Nor was there any significant difference between treatments for carcass quality traits.

TABLE 1-A. AH-BC-700: COMPOSITION OF RATIONS FED

Ingredient	Soybean Meal	Urea	DPW	1/2 DPW 1/2 Soy	1/2 DPW 1/2 Urea
Corn silage	20.00	20.00	20.00	20.00	20.00
Rolled sh. corn	73.29	77.42	47.29	64.94	68.83
Soy	4.92			3.26	
Urea		.786			.563
DPW			31.97	10.54	9.34
T.M. Salt	.500	.500	.500	.500	.500
Dicalcium phosphate	.500	.500		.250	.250
Limestone	.550	.550		.275	.275
Sodium sulfate	.200	.200	.200	.200	.200
Vit. A (10,000 I.U./g)	.033	.033	.033	.033	.033
Vit. D (9,000 I.U./g)	.011	.011	.011	.011	.011
Cost per ton**	$44.00	$40.16	$36.20	$41.40	$40.00

*Value expressed as a percent of ration dry matter

**Ration cost based on: 35% DM corn silage, $8.50 T, sh. corn $1.26 bu, soybean meal $100 T, urea $80 T, DPW $30 T, TM salt $60 T, dicalcium phosphate $80 T, limestone $40 T, sodium sulfate $120 T, vitamin A and D premix $10 cwt.

TABLE 2-A. AH-BC-700: PROTEIN SUPPLEMENTS COMPARED
(May 7, 1970 to Sept. 17, 1970)

134 Day Test	Soybean Meal	Urea	DPW	1/2 DPW 1/2 Soy	1/2 DPW 1/2 Urea
Lot number	42	36	38	37	35
No. yearling steers	9	9	9	9	9
Av. initial wt., kg	314	309	313	315	313
Av. final wt., kg	518	481	481	491	498
Av. daily gain, kg	1.52Aa	1.41ABa	1.25Bb	1.31ABb	1.38ABb
Daily Feed, kg 85% DM:					
Total	10.60	10.19	13.04	10.65	10.06
Percent of body weight	2.55	2.50	3.28	2.64	2.48
Feed Efficiency					
Feed per kg gain, kg	3.16	3.29	4.74	3.70	3.32
Feed cost/cwt gain 1/	$15.31	$15.03	$18.87	$16.84	$14.58
Carcass Evaluation					
Carcass grade 2/	12.12	13.23	11.24	12.56	12.45
Marbling score 3/	14.89	19.00	13.56	17.45	17.00
Fat thickness, in.	.66	.78	.57	.69	.70
Rib eye area, sq in.	11.13	11.42	11.15	11.37	12.04
% K.H.P. fat 4/	2.85	3.00	2.66	2.85	2.85
% B.T.R. cuts 5/	48.09	47.71	49.34	48.36	48.81
Dressing percent	58.53	58.91	57.21	59.29	58.66
Carcass price/cwt $	$46.79	$46.79	$46.13	$45.57	$45.57

1/ Ration cost based on: 35% DM corn silage, $8.50 T, sh.corn $1.26 bu, soybean meal $100 T, urea $80 T, TM salt $60 T, dicalcium phosphate $80 T, DPW $30 T, limestone $40 T, sodium sulfate $120 T, vitamin A and D premix $10 cwt.

2/ Carcass grade code - Good = 9, 10, 11; Choice = 12, 13, 14.

3/ Marbling code - Small = 10, 11, 12; Modest = 13, 14, 15; Moderate = 16, 17, 18.

4/ Percent of carcass weight in kidney, heart and pelvic fat.

5/ Percent of carcass weight in boneless, trimmed, retail cuts.

Significance: A,B - Values having different superscript are significantly different (P<.01).
a,b - Values having different superscript are significantly different (P<.05).

APPENDIX B. PERFORMANCE AND BLOOD ANALYSES OF GROWING TURKEYS FED DEHYDRATED POULTRY ANAPHAGE[1]

By

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INTRODUCTION

A major problem confronting the poultry industry is waste management. During recent years, the development and growth of the industry has resulted in the production of tremendous amounts of manure and disposal has become a health and economics problem in many places. Logically, a system of poultry waste management emphasizing utilization would be of value to the poultry producer.

The inclusion of digestive waste in the diets of poultry as a specific feed ingredient is a relatively new idea, although numerous reports have appeared on the feeding of dehydrated poultry anaphage to growing chicks (24, 23, 1, 26 and 9) and laying hens (8, 10, 11, 25, 7 and 17). However, a review of the literature revealed a lack of data on feeding dehydrated poultry anaphage to turkeys. This investigation was undertaken to determine whether DPW could be substituted for corn in a turkey growing ration.

PROCEDURE

Commercial 9-week-old straight run Broad Breasted White turkeys were weighed and randomly assigned to 3 x 5.4 m pens. Two replicates of 19 birds each were randomly assigned to four diets which contained 0, 5, 10 and 30% dehydrated poultry anaphage (Table 1-B). The dehydrated poultry anaphage used was manure collected from caged laying chickens, dehydrated (22) and mixed in a vertical mixer prior to incorporation into the diets. Chemical analysis of the dehydrated poultry anaphage is given in Table 2-B.

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The word "anaphage", which refers to a dehydrated poultry manure product, was coined by Polin (18) at Michigan State University. It was derived from the Greek words, Ana (again) and Phage (to eat).

The diets were designed to be isocaloric with the assumption that the metabolizable energy value of dehydrated poultry anaphage was 614 Kcal per kg (19). Changes were also made in the levels of the dicalcium phosphate and limestone in an attempt to keep the calcium-phosphorus level the same; however, in the diet with 30% dehydrated poultry anaphage, the level increased because of the amount in the anaphage.

Feed and water were supplied ad libitum. Feed consumption was recorded for each treatment group by replication and mortality was recorded as it occurred. A 12-hour artificial light day was provided throughout the entire 8-week (9-17 weeks of age) experimental period.

At 17 weeks of age, 16 birds (8 males and 8 females) were selected at random from each of the four treatments for blood samples. From these samples, plasma uric acid was determined by the ultraviolet technique (21), phosphorus was determined by a calometric method (14) and zinc was determined by atomic absorption spectroscopy on a Jarrell-Ash atomic absorption spectrophotometer (Model 82-516, Jarrell-Ash Co., Waltham, Mass.).

Statistical analyses were performed using methods of covariance and analysis of variance (15) and Dunnett's Allowance (5).

RESULTS

Livability was not affected by feeding poultry anaphage to growing turkeys. Two birds receiving the 10% dietary level of poultry anaphage died during the eight-week experimental period; however, death was attributed to injury rather than from dietary effect. One bird in the 30% poultry anaphage treatment group was eliminated from analysis because the bird was obviously abnormal (undetermined health problem). In terms of appearance, the birds that received the poultry anaphage had the same coloring, activity and vitality.

Average body weight of male and female growing turkeys was not significantly ($P \geq .05$) affected by feeding poultry anaphage for eight weeks (Table 3-B), although a trend for an average lowered body weight was observed in the birds fed 30% poultry anaphage.

Total weight gain for the 9- to 17-week age period (Table 7-B) was not significantly ($P \geq .05$) affected by feeding poultry anaphage to growing turkeys, although the treatment significance level was $P = .061$ (Table 4-B). The arithmetic average body weight gain was 0.33 kg less for the birds fed 30% poultry anaphage than for the control group.

Feed efficiency for the entire eight-week growing period was inversely related to the amount of poultry anaphage incorporated into the diet (Table 5-B). In comparison to the control group, 1.5, 3.8 and 8.4% more feed was required to produce one kg body weight gain, respectively, for the

5, 10 and 30% poultry anaphage-fed turkeys.

The results of the plasma uric acid analyses are presented in Table 6-B. Despite a trend for the plasma uric acid to increase as the level of dietary anaphage increased, no significant ($P \geq .05$) effect was noted. An average value of 2.78 mg/100 ml plasma was observed in the control group, in comparison to 3.38mg/100 ml plasma for the three anaphage-fed treatment groups. No significant ($P \geq .05$) difference was noted between the males and females.

The results of the plasma phosphorus analyses are presented in Table 7-B. A significant ($P \leq .01$) treatment effect was observed with an average of 3.64 mg phosphorus per 100 ml plasma in the control group in comparison to 4.78, 4.72 and 6.02 mg/100 ml plasma, respectively, for the 5, 10 and 30% poultry anaphage-fed treatment groups. No significant ($P \geq .05$) difference was noted between the males and females.

The results of the plasma zinc analyses are presented in Table 8-B. A significant ($P \leq .01$) treatment effect was observed and was due to a lower plasma zinc level observed in the turkeys fed 5% poultry anaphage. The 30% poultry anaphage-fed birds had plasma zinc levels equal to the control-fed birds. A significant ($P \leq .01$) sex difference, with lower values being observed in the females, was noted.

DISCUSSION

Since the average body weight gain of growing turkeys (9 to 17 weeks of age) was not significantly ($P \geq .05$) affected by including dehydrated poultry anaphage in the diet, poultry anaphage could substitute for corn in the diet of growing turkeys.

A 30% substitution level is questionable, because a 0.33 kg per bird average lower weight gain was observed in the birds fed 30% poultry anaphage, in comparison to the control birds fed no poultry anaphage. Furthermore, the treatment significance level was $P=.061$, and was obviously due to the lower body weight gain in 30% dehydrated poultry anaphage treatment group (Table 4-B). Body weight gain data are in agreement with those of (4, 9, 2 and 17).

Feed efficiency, as shown in Table 5-B, was inversely related to the level of dehydrated poultry anaphage incorporated in the diet; that is, the higher the level of anaphage, the poorer the feed efficiency. This feed efficiency result is in agreement with that obtained (9, 11 and 12), with chicks and laying hens; (2) with chicks; and (6 and 16) with laying hens. However, it is in opposition to the data of Quisenberry and Bradley (20), who obtained no adverse effect on feed conversion of laying hens when fed poultry manure in diets calculated to be isonitrogenous and isocaloric to the basal diet, which contained no manure.

Perhaps the assumed metabolizable energy value was in error, since Flegal _et al_. (13) reported that the nutrient quality of dehydrated poultry manure was lower the longer the manure was stored prior to dehydration.

A significant ($P \leq .05$) effect of dietary dehydrated poultry anaphage was not observed on plasma uric acid values despite a reported value of 6.3% uric acid in dehhdrated poultry anaphage (3). Thus, the growing turkey apparently is able to maintain an equilibrium in this regard.

Plasma phosphorus level was significantly ($P \leq .01$) increased by feeding dietary poultry anaphage. The most obvious increase was in the turkeys fed the 30% dehydrated poultry anaphage level. This apparently reflects the phosphorus level of the diet because the 0, 5 and 10% dehydrated poultry anaphage diets had nearly equal calculated phosphorus values (0.84, 0.86 and 0.85%, respectively); whereas, the 30% dehydrated poultry anaphage diet had 1.23% calculated phosphorus.

SUMMARY

An experiment was conducted to study the effect of feeding dehydrated poultry anaphage on the performance and blood constituents of growing turkeys from 9 to 17 weeks of age.

The overall body weight gain from 9 to 17 weeks of age was not significantly ($P \geq .05$) altered by feeding dietary dehydrated poultry anaphage. However, a numerical decrease of 0.33 kg per bird, in comparison to the control group, was observed in the birds that received 30% dehydrated poultry anaphage in their diet.

Feed efficiency was inversely related to the level of anaphage in the diet, with conversion figures being 3.35, 3.40, 3.48 and 3.63 kg feed per kg body weight gain for the 0, 5, 10 and 30% anaphage diet, respectively. Mortality was not affected by feeding poultry anaphage. No significant ($P \leq .05$) effect on plasma uric acid levels was observed as a result of feeding poultry anaphage. Plasma phosphorus level was significantly ($P \leq .01$) increased by feeding 30% poultry anaphage.

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TABLE 1-B. DIET COMPOSITION

	Percentage of Diet			
		Poultry Anaphage		
Ingredient	Control	5%	10%	30%
Corn, ground yellow	60.0	54.0	48.2	19.0
Soybean oil meal, 49%	27.0	27.0	27.0	27.0
Alfalfa leaf meal, 17%	2.5	2.5	2.5	2.5
Fish meal, 60%	2.5	2.5	2.5	2.5
Meat & bone meal, 50%	2.5	2.5	2.5	2.5
Animal fat	2.5	4.5	6.0	15.5
Salt, iodized	0.4	0.4	0.4	0.4
Dicalcium phosphate	1.5	1.0	0.3	----
Limestone	0.5	----	----	----
Vitamin-mineral premix (1)	0.6	0.6	0.6	0.6
Poultry Anaphage	----	5.0	10.0	30.0

(1) Contained per kg premix: 1,320,000 U.S.P. units vitamin A; 3,666,667 I.C. units vitamin D_3; 880 mg riboflavin; 1760 mg pantothenic acid; 7.3 g niacin; 90.9 g choline chloride; 256 mg folic acid; 2.2 mg B_{12}; 1,100 I.U. vitamin E; 294 mg menadione sodium bisulfite; 146 mg thiamine mono-citrate; 1.533% Mn; 0.02% I; 0.161% Cu; 0.0051% Co; 1.0% Zn; 0.5% Fe.

Calculated Analysis

Protein, %	21.7	21.7	21.7	21.2
Metab. Energy, Kcal/kg	3048	3069	3059	3081
Calcium, %	1.04	1.04	1.19	2.37
Phosphorus, %	0.84	0.86	0.85	1.23

TABLE 2-B. COMPOSITION OF THE DEHYDRATED POULTRY ANAPHAGE USED IN THE EXPERIMENTAL DIETS

Component	Percentage
Calcium	6.3
Phosphorus	2.6
Crude fiber	15.6
Ether extract	3.4
Water	6.7
Crude protein	19.5
Non-protein nitrogen	1.5
Protein nitrogen	1.6

TABLE 3-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAPHAGE ON THE 17-WEEK BODY WEIGHT OF GROWING TURKEYS

	Average Body Weight (kg)		
Item	Male	Female	Sexes Combined
Treatment:			
Control	7.54 ± .26 (21)	5.99 ± .11 (17)	6.85 ± .23(38)
5% anaphage	7.64 ± .29 (20)	5.96 ± .11 (18)	6.85 ± .25(38)
10% anaphage	7.65 ± .20 (20)	5.75 ± .14 (16)	6.80 ± .28(36)
30% anaphage	7.46 ± .23 (17)	5.68 ± .16 (20)	6.50 ± .25(37)

Source:	Sum of Squares	D.F.	Mean Square	F-Value	Significance Level
Treatment (T)	1.1408	3	0.3803	0.870	.458
Sex (S)	107.4286	1	107.4286	245.796	<.001
Replication (R)	0.0368	1	0.0368	0.084	.772
T x S	0.6745	3	0.2248	0.514	.673
T x R	1.2579	3	0.4193	0.959	.414
R x S	0.6420	1	0.6420	0.0961	.757
T x R x S	0.3887	3	0.1296	0.2965	.828
Error	58.1295	133	0.4371		

± Standard error of mean
(149) Number of birds

TABLE 4-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAPHAGE ON THE 9- to 17-WEEK BODY WEIGHT GAIN OF GROWING TURKEYS

	Average 9- to 17-Week Body Weight Gain (kg)		
Item	Male	Female	Sexes Combined
Treatment:			
Control	4.20 ± .18 (21)	3.37 ± .10 (17)	3.82 ± .14 (38)
5% anaphage	4.31 ± .21 (20)	3.29 ± .08 (18)	3.82 ± .16 (38)
10% anaphage	4.29 ± .17 (20)	3.07 ± .11 (16)	3.75 ± .18 (36)
30% anaphage	4.11 ± .12 (17)	2.97 ± .09 (20)	3.49 ± .15 (37)

Source:	Sum of Squares	D.F.	Mean Square	F-Value	Significance Level
Treatment (T)	1.5232	3	0.5077	2.519	.061
Sex (S)	39.4158	1	39.4158	195.534	<.001
Replication (R)	0.0240	1	0.0240	0.119	.731
T x S	0.8346	3	0.2782	1.380	.252
T x R	2.1444	3	0.7148	3.546	.016
R x S	0.0005	1	0.0005	0.003	.959
T x R x S	0.1213	3	0.0404	0.201	.896
Error	26.8102	133	0.2016		

± Standard error of mean
(149) Number of birds

TABLE 5-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAPHAGE ON THE FEED CONVERSION OF GROWING TURKEYS

Treatment	Feed Conversion (kg feed/kg body wt. gain)		
	9-13 Wks.	13-17 Wks.	9-17 Wks.
Control	2.92	4.04	3.35
5% anaphage	2.84	4.29	3.40
10% anaphage	3.15	3.93	3.48
30% anaphage	3.11	4.38	3.63

TABLE 6-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAPHAGE TO GROWING TURKEYS ON THE LEVEL OF PLASMA URIC ACID

Item	Plasma Uric Acid Level (mg/100 ml) (1) Male	Female	Sexes Combined
Treatment:			
Control	2.59 ± .57	2.97 ± .62	2.78 ± .59
5% anaphage	3.09 ± .39	2.87 ± .75	2.98 ± .57
10% anaphage	3.67 ± .11	3.59 ± .71	3.63 ± .38
30% anaphage	3.19 ± .52	3.88 ± .66	3.54 ± .59

Source:	Sum of Squares	D.F.	Mean Square	F-Value	Significance Level
Treatment (T)	6.9979	3	2.3326	1.507	0.225
Sex (S)	0.2823	1	0.2823	0.1823	0.671
Replication (R)	4.7035	1	4.7035	3.039	0.088
T x S	2.7726	3	0.9242	0.5971	0.620
T x R	18.7051	3	6.2350	4.028	0.012
R x S	2.5400	1	2.5400	1.6410	0.206
T x R x S	6.7692	3	2.2564	1.4578	0.238
Error	74.2969	48	1.5479		

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(1) 8 males and 8 females per treatment
±Standard error of mean

TABLE 7-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAPHAGE TO GROWING TURKEYS ON THE LEVEL OF PLASMA PHOSPHORUS

Item	Plasma Phosphorus Level (mg/100 ml) (1) Male	 Female	 Sexes Combined
Treatment:			
Control	3.41 ± .20	3.86 ± .24	3.64 ± .22
5% anaphage	4.88 ± .57	4.67 ± .38	4.78 ± .48
10% anaphage	5.09 ± .64	4.35 ± .51	4.72 ± .58
30% anaphage	6.53 ±1.16	5.51 ± .79	6.02 ± .98

Source:	Sum of Squares	D.F.	Mean Square	F-Value	Significance Level
Treatment (T)	433.5893	3	144.5298	233.981	<.001
Sex (S)	0.0848	1	0.0848	0.137	.713
Replication (R)	3.3994	1	3.3994	5.503	.023
T x S	2.9589	3	0.9863	1.597	.202
T x R	5.6377	3	1.8792	3.042	.038
R x S	0.0749	1	0.0749	0.121	.729
T x R x S	0.7661	3	0.2554	0.413	.744
Error	29.6508	48	0.6177		

(1) 8 males and 8 females per treatment
±Standard error of mean

TABLE 8-B. EFFECT OF FEEDING DEHYDRATED POULTRY ANAHPAGE TO GROWING TURKEYS ON THE LEVEL OF PLASMA

	Plasma Zinc Level (mg/100 ml)(1)		
Item	Male	Female	Sexes Combined
Treatment:			
Control	1.62 ± .11	1.58 ± .02	1.60 ± .06
5% anaphage	1.57 ± .02	1.52 ± .00	1.55 ± .01
10% anaphage	1.58 ± .03	1.58 ± .02	1.58 ± .02
30% anaphage	1.62 ± .02	1.59 ± .03	1.61 ± .02

Source:	Sum of Squares	D.F.	Mean Square	F-Value	Significance Level
Treatment (T)	0.0473	3	0.0158	6.302	.001
Sex (S)	0.0272	1	0.0272	10.886	.002
Replication (R)	0.0049	1	0.0049	1.959	.168
T x S	0.0069	3	0.0023	0.921	.438
T x R	0.0171	3	0.0057	2.291	.090
R x S	0.0016	1	0.0016	0.640	.428
T x R x S	0.0084	3	0.0028	1.125	.349
Error	0.1201	48	0.0025		

(1) 8 males and 8 females per treatment

±Standard error of mean

APPENDIX C. FERTILITY AND HATCHABILITY IN SINGLE COMB WHITE LEGHORNS FED VARYING LEVELS OF POULTRY ANAPHAGE

By

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INTRODUCTION

Due to the lack of information concerning the influence of feeding various levels of poultry anaphage to laying hens on fertility and hatchability, the following experiment was conducted.

PROCEDURE

One hundred and twenty ready-to-lay S.C.W.L. females and 24 S.C.W.L. males, six months of age, were randomly selected for this experiment. The birds were placed in a stair-step colony cage system. The females were assigned, five birds each, into 24 colony cages (56 cm x 61 cm) on the lowest deck. The males (one to each group of five females) were placed in corresponding cages on the upper deck.

The entire cage system was located in a windowless house. Room temperature was maintained at 14.0° - 16.0°C. The birds were provided with 14 hours' artificial lighting (6 a.m. - 8 p.m.).

The 24 groups of five females plus one male were randomly assigned four experimental diets, with six replicate groups being fed each diet. The composition of the four experimental diets is outlined in Table 1-C. The basal diet was a typical corn/soya layer ration. The other three diets had three levels of poultry anaphage (formerly called dried poultry waste or DPW) at levels of 6.25, 12.5, and 25.0%.

The anaphage replaced an equivalent percentage of corn from the basal diet. The poultry anaphage used in the experimental diets was from a single batch processed at the Michigan State University Poultry Research Center.

The analysis of the poultry anaphage used in the experimental diets is presented in Table 2-C. Feed and water were supplied *ad libitum* to both males and females throughout the entire experiment.

In the first three weeks of the experiment, only egg production data were recorded. Beginning during the fourth week, the females in each pen were artificially inseminated with semen collected from the respective males assigned to each pen of females.

The artificial insemination procedure used was done according to the method of Burrows and Quinn (1). Semen ejaculates, from individual males from the same treatment, were pooled and then extended with 1.0 ml of physiological saline. An average of 0.2 ml of the extended semen was used to inseminate each female.

During Phase I (week 4 to week 11) of the experiment, all females were inseminated once each week. The inseminations were increased to twice per week (second and fifth day of each week) during Phase II (week 12 to week 15) of the experiment.

Egg production was recorded daily throughout the experimental period. All eggs produced were marked and stored overnight on flats in the service building. Eggs from each of the hens were set in incubators within 24 hours of being laid.

The eggs were incubated in a Jamesway 252 forced draft incubator. The incubators were cleaned and fumigated prior to use in this project. The average readings of the thermometers in the incubators were 37.7°C (dry bulb) and 31.7°C (wet bulb). While in the incubator, the eggs were turned once every two hours. After 18 days of incubation, the daily production of eggs was set in separate incubator trays. The eggs were mass candled. The infertiles were removed and the fertiles were transferred to the hatcher.

After 21 days of incubation, the number of chicks hatched, eggs pipped, chicks dead in shell, and number of infertiles was recorded.

Fertility was expressed as the percent total fertile eggs of the total eggs set. Hatchability was expressed as the percent pipped and hatched chicks of the total fertile eggs set.

RESULTS

Egg Production (0-15)

The birds fed the diets containing the different levels of poultry anaphage had a pooled average hen day egg production of 70.85%, as compared to 69.56% obtained from the pullets fed the control ration (Table 3-C).

There was statiscally no significant ($P \geq .05$) difference in the percent egg production from the birds fed any of the poultry anaphage supplemented diets and the egg production of the birds fed the control diet.

Fertility and Hatchability Trends (Table 4-C) - Phase I (week 4 to 11)

The percent fertility during this period of the experiment showed no significant ($P \geq .05$) differences between the fertility of eggs from pullets fed the control diet (78.8%) and those fed the poultry anaphage supplemented diets (75.1%).

The percent hatchability of the fertile eggs incubated during this period was high (94.6%). Again, there was no significant ($P \geq .05$) difference between the control (hatchability 94.7%) and the poultry anaphage-supplemented treatments (hatchability 94.5%).

Phase II (week 12 to 15)

With continued feeding of the experimental diets, the average fertility of the eggs from the birds fed the poultry anaphage supplemented diets declined by 1.7%, as compared to their average fertility during Phase I. The fertility of these eggs, however, showeda significant (P≤.01) decline from that obtained from the birds fed the control ration. Among the percent fertility figures from the birds fed the diets containing poultry anaphage, the highest percent fertility was recorded from the birds fed the diet supplemented with 25.0% anaphage.

As in Phase I, the percent hatchability remained high (97.2%) and there was no significant (P≥.05) effect of the poultry anaphage supplemented diets on hatchability.

Overall Fertility and Hatchability (week 4 to week 15)

Fertility data (Table 5-C) for the entire period of the experiment reflected the decline in fertility observed during Phase II or the last four weeks of the experiment. There was an overall decline of 7.3% in fertility in the birds fed the poultry anaphage supplemented diets when compared to those fed the basal diet. Again, as was seen in the fertility figures in Phase II, the highest percent fertility figures were obtained from the birds fed the diet containing 25.0% poultry anaphage.

The percent hatchability of the fertile eggs from the control pens was 97.3% (Table 6-C). The mean percent hatchability of fertile eggs from the birds fed the poultry anaphage diets was lower by 1.8% but the difference was not significant (P>.05).

SUMMARY

Levels of poultry anaphage, ranging 6.25 to 25.0% substituted for corn in typical layer rations and fed to S.C.W.L. pullets for 15 weeks had no effect on overall hen housed egg production.

Percent fertility of eggs produced in the period of week 4 to week 11 by the birds fed the poultry anaphage supplemented diets showed no statistical (P≥.05) difference from those fed the corn/soya diet.

The poultry anaphage supplemented diets had no significant (P≥.05) effect on the percent hatchability of fertile eggs produced during week 4 to week 11 of the experiment.

With continued feeding of the diets that contained poultry anaphage from week 11 to week 15, the mean percent fertility declined by 1.7%, when compared to the fertility data from the corresponding earlier period.

The poultry anaphage supplemented diets continued to show no effect on percent hatchability of fertile eggs when the diets were fed for the continued period week 11 to week 15.

The inconsistent trends in fertility among the birds fed increasing levels of supplemental poultry anaphage need to be further investigated. More valid data on fertility could be obtained using a combined system of natural mating and artificial insemination.

COMMENTS

The males used in this experiment were not selected on the basis of their suitability to an artificial method of semen collection. Some males, especially those on the treatments fed the 12.5% poultry anaphage, never produced semen, while others produced only a very small quantity of the semen used toward the pooled volume. To overcome this limitation in future experiments, it is suggested that all males be tested for suitability for artificial semen collection and also to adopt a combination system of natural mating and artificial insemination. This method should provide fertility figures not affected by limitations due to insemination techniques.

The diets containing poultry anaphage were not adjusted for equal calcium and phosphorus content and M.E. calorie: percent protein ratio.

It is proposed to extend this investigation using broiler-type breeders.

REFERENCES

Burrows, W. H. and J. P. Quinn (1937). The collection of spermatozoa from the domestic fowl and turkey. Poultry Sci. 16: 19-24.

TABLE 1-C. COMPOSITION OF EXPERIMENTAL DIETS

Ingredients	Experimental Diets #1	#2	#3	#4
	(Percent of Ration)			
Corn	68.05	61.80	55.55	43.05
Soybean meal (49%)	16.20	16.20	16.20	16.20
Alfalfa meal (17%)	2.50	2.50	2.50	2.50
Meat & bone meal (50%)	3.50	3.50	3.50	3.50
Fish meal (60%)	1.50	1.50	1.50	1.50
Limestone	6.00	6.00	6.00	6.00
Dicalcium phosphate	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25
Fat	0.50	0.50	0.50	0.50
Vitamin mineral premix	0.50	0.50	0.50	0.50
Poultry anaphage	--	6.25	12.50	25.00
	100.00	100.00	100.00	100.00
Calculated Analysis:				
Crude protein (%)	17.00			
Crude fat (%)	3.68			
M.E. (Kcal/g)	2.90			
Calcium/phosphorus ratio	4.30			

TABLE 2-C. ANALYSIS OF POULTRY ANAPHAGE USED IN THE EXPERIMENTAL DIETS

Constituent	Percent
Kjeldahl (total) nitrogen	4.25
Non-protein nitrogen	4.29
Moisture	9.56
Ether extract	2.25
Crude fiber	12.30
Ash	21.84
Calcium	6.89
Phosphorus	2.23

TABLE 3-C. THE EFFECT OF POULTRY ANAPHAGE ON PERCENT EGG PRODUCTION

Treatment	No. of Hens Per Treatment	Hen Days	Total Egg Production	Mean Percent Production	
Control	29	272	1419	69.56	
+ 6.25% Poultry Anaphage	30	340	1428	70.00	
+12.50% Poultry Anaphage	30	340	1509	73.97	70.8
+25.00% Poultry Anaphage	30	340	1399	68.58	

Analysis of Variance of Percent Egg Production

Source	df	Ms
Treatment	3	95.1
Reps	5	66.8
Control vs. treatment	(1)	0.3
Poultry anaphage levels	(2)	142.7
Error	15	39.1
Total	23	

TABLE 4-C. TRENDS IN FERTILITY AND HATCHABILITY WITH (a) CONTINUED FEEDING OF POULTRY ANAPHAGE (b) INCREASED WEEKLY INSEMINATION

	Phase I (Week 4 to 11)				Phase II (Week 12 to 15)			
	One Insemination Per Week				Two Inseminations Per Week			
Treatment	Percent Fertility		Percent Hatchability		Percent Fertility		Percent Hatchability	
Control	78.8		94.7		90.0		99.1	
+ 6.25% Poultry Anaphage	79.2	75.1	92.8	94.5	73.9	73.4	96.7	97.2
+12.50% Poultry Anaphage	67.8		93.9		65.9		98.1	
+25.00% Poultry Anaphage	78.5		97.0		80.4		97.0	
Overall Mean	76.1		94.6		77.5		97.7	

Analysis of Variance of Fertility and Hatchability Data

Source	df	Fertility	Hatchability	Fertility	Hatchability
Treatment	3	181.2	16.9	626.8*	7.6
Reps	5	83.7	61.3	78.9	4.7
Control vs. treatment	(1)	57.5	0.02	1240.9**	16.2
Poultry anaphage levels	(2)	243.0	25.4	320.0	3.1
Error	15	71.8	14.2	74.7	4.6
Total	23				

*P≤.05
**P<.01

TABLE 5-C. THE EFFECT OF POULTRY ANAPHAGE ON PERCENT FERTILITY

		Production through 57 days			
Treatment	No. of Hens Per Treatment	Total Eggs Set	Total Eggs Fertile	Mean Percent Fertility	
Control	29	1190	1010	83.9	
+ 6.25% Poultry Anaphage	30	1213	943	77.4	
+12.50% Poultry Anaphage	30	1265	852	67.0	74.6
+25.00% Poultry Anaphage	30	1173	933	79.4	

Analysis of Variance of Fertility Data

Source	df	Ms
Treatment	3	307.4*
Reps	5	44.3
Control vs. treatment	(1)	387.8**
Poultry anaphage levels	(2)	267.2**
Error	15	23.4
Total	23	

*P≤.05
**P≤.01

TABLE 6-C. THE EFFECT OF POULTRY ANAPHAGE ON PERCENT HATCHABILITY

		Production Through 57 Days			
Treatment	No. of Hens Per Treatment	Total Eggs Fertile	Total Eggs Hatched	Mean Percent Hatchability	
Control	29	1005	981	97.3	
+ 6.25% Poultry Anaphage	30	943	881	93.7	95.5
+12.50% Poultry Anaphage	30	852	815	95.6	
+25.00% Poultry	30	933	909	97.3	

Analysis of Variance of Hatchability Data

Source	df	Ms
Treatment	3	18.05
Reps	5	15.06
Control vs. treatment	(1)	14.12
Poultry anaphage levels	(2)	20.10*
Error	15	5.31
Total	23	

*P≤.05

APPENDIX D. THE FEASIBILITY OF USING WASTE MATERIALS AS SUPPLEMENTAL FISH FEED

by

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In recent years public and professional awareness of environmental pollution and the necessity for preservation of natural resources has stimulated greater interest in recycling of waste materials (3). Research has been initiated on the possible use of wastes as a component of animal feed.

Green et al. (7) for example, have considered using fish solubles as a nitrogen supplement in mushroom compost and for peptone in microbiological media. Walker (10) investigated the use of crawfish waste as a supplemental diet for channel catfish and those fish fed on raw and pelletized waste exhibited a weight gain of 50% and 75%, respectively, of that of controls. Some encouraging results have also been reported in using dried poultry waste as a supplemental diet for chicks (5). The economic advantages of large, more efficient poultry operations have, in turn, itensified the problem of manure disposal. A partial solution to this problem is found in Fowler's report (6) that channel catfish consuming feed consisting of 25% dried poultry waste grew better than controls.

Since the nutrient content of sewage sludge and dried poultry waste showed high values in protein, crude fat and carbohydrate, a study was carried out to investigate the feasibility of using such waste materials as supplemental fish feed (Table 1-D).

MATERIALS AND METHODS

The nutrient value of sewage sludge and dried poultry waste (DPW) were tested in two experiments using the growth rate of goldfish, *Carassius auratus* in one and channel catfish, *Ictalurus punctatus* fingerlings in the other.

All groups of fish were placed in twenty-gallon tanks and were fed once daily. Water exchange for each tank was 0.5 gpm. Each tank was aerated with an airstone to keep dissolved oxygen above 5 ppm. The pH value, determined once every two weeks, ranged from 7.4 to 8.2. Ammonia concentration, total alkalinity and total hardness were determined once (on the beginning of the third month of the experiment) and found to be 0.09 ppm, 296 ppm and 260 ppm, respectively.

A 30% sewage sludge diet was prepared by combining three parts sludge and seven parts ground salmon feed (Ewos F49). The sewage sludge, as filtercake, was obtained from the primary settling tank in the waste water treatment plant of East Lansing, Michigan. The solid sludge, composed of 62% volatile materials and 38% ash, was sun dried and ground into fine particles. The two mixes were then granulated and pelletized to 2.5 x 4.0 mm.

The DPW was obtained from the Department of Poultry Science of Michigan State University. The DPW and salmon feed were ground into fine particles and mixed to form pellets in the same manner as with the sewage sludge pellets. Three varying mixes, 30%, 70% and 100% DPW diets were made.

In the goldfish experiment 20 fish were placed in each of the three tanks and were fed amounts equal to 3% of their body weight daily. Fish in one tank were given salmon feed as controls, while fish in the other two tanks were given feed consisting of 30% sewage sludge diet and 30% DPW diet.

In the catfish study 18 fish were placed in each of the 12 tanks. The tanks were separated into three groups of four tanks each. The three groups differed in the level of feed received, with fish in the first, second and third group being 2%, 3% and 4% of their body weight, respectively. Within each group, fish from different tanks were fed with different types of diets: fish in the first, second, third and fourth tanks were fed 0% (control), 30%, 70% and 100% DPW diets, respectively. The purpose of having three different levels of feed was to determine the level of feeding that would produce the most efficient feed conversion.

Because of unequal initial weights, comparison of growth among different groups was based on the average monthly percent weight gains for fish from each tank. In the statistical analysis, adjustment for the unequal number of fish due to accidental losses were made accordingly. An analysis of variance of a randomized block design and Dunnett's t-test (8) were used to detect significant differences in growth between the experimental and control fish. Dunnett's equation is as follows:

$t_D = (y_c - y_i) / (ms_E (1/r_c + 1/r_i))^{\frac{1}{2}}$, where

t_D = Dunnett's t-test

y_c = mean percent growth of control

y_i = mean percent growth of experimental

ms_E = mean square error

r_c = number of replications of control

r_i = number of replications of experimental

The total caloric values for different feeds were calculated from the percent composition of the feed and the corresponding energy value. The average values for protein, fat and carbohydrate used were 3.9, 8.0 and 1.6

TABLE 1-D. NUTRIENT ANALYSIS OF DIFFERENT FEED (EXPRESSED AS PERCENT)

Type of Feed	Digestible Carbo-hydrate	Calcium	Phos-phorus	Ash	Crude Fiber	Ether Extract	H_2O	Kjeldahl N	Crude Protein	Non-protein N	Corrected[1] Protein
Control (salmon feed)	27.70	1.94	1.44	9.60	2.47	4.51	6.46	7.87	49.19	1.92	37.19
Sludge	22.46	2.35	2.35	29.16	10.80	11.61	6.16	3.17	19.81	.85	14.50
Dried poultry waste	41.75	5.30	2.11	18.13	10.43	1.56	7.69	3.27	20.44	1.21	12.88

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[1] Corrected protein = (6.25) x (%Kjeldahl N - % non-protein N).

TABLE 2-D. THE CALORIC VALUE OF DIFFERENT TYPES OF FEED

Type of Feed	Corrected Protein	Ether Extract	Digestible Carbohydrate	Total
		Kcal/g		Kcal
Control (salmon feed)	145.0	36.1	44.3	225.4
30% sludge mix (30% sludge + 70% salmon feed)	118.5	53.1	41.8	213.4
30% dried poultry waste mix (30% DPW + 70% salmon feed)	116.6	29.1	51.1	196.7

TABLE 3-D. PERCENT GROWTH (%) IN BODY WEIGHT PER MONTH AND INITIAL AVERAGE WEIGHT (g) IN DIFFERENT DIET TREATMENTS OF GOLDFISH, Carassius auratus

Type of feed	Initial Average weight (g)	Percent growth (%) Time (month) 1	2	3	4	5
Control	5.90	49.7	55.2	43.1	29.2	9.6
30% sludge mix	4.53	57.4	54.3	40.5	25.9	10.3
30% DPW mix	6.28	56.7	64.6	61.2	26.6	19.1

TABLE 4-D. PERCENT GROWTH (%) IN BODY WEIGHT PER MONTH ON DIFFERENT DIET TREATMENTS AND INITIAL AVERAGE WEIGHT (g) OF CHANNEL CATFISH, *Ictalurus punctatus*

Time	Group 1 (Feed = 2% b.w.)			Group 2 (Feed = 3% b.w.)			Group 3 (Feed = 4% b.w.)		
(month)	Control	30% DPW	70% DPW	Control	30% DPW	70% DPW	Control	30% DPW	70% DPW
1	38.4	21.6	19.2	56.7	11.5	20.3	55.6	42.0	12.7
2	56.3	28.5	24.4	52.7	50.1	26.4	67.4	45.7	21.5
3	51.7	48.7	39.0	66.1	65.6	45.5	78.2	58.0	35.0
4	44.0	41.3	35.5	83.4	17.5	26.7	49.2	28.3	56.0
5	25.3	23.5	12.7	29.1	12.7	12.1	53.8	19.9	11.6
Int Ave. wt. (g)	4.25	3.61	3.75	3.72	5.03	3.50	4.50	3.49	3.38

TABLE 5-D. FEED CONVERSION (FEED GIVEN/GROWTH IN WEIGHT) OF THREE TYPES OF FEED IN THREE LEVELS OF FEED (% b.w.) IN CHANNEL CATFISH, *Ictalurus punctatus*

Time	Control (0% DPW)			30% DPW			70% DPW		
	Percent body weight (%)			Percent body weight (%)			Percent body weight (%)		
(months)	2	3	4	2	3	4	2	3	4
1	1.57	1.58	2.16	2.77	8.18	2.89	3.13	4.44	9.30
2	1.06	1.70	1.78	2.12	1.79	2.63	2.47	3.41	5.61
3	1.16	1.36	1.53	1.23	1.45	2.17	1.63	1.98	3.46
4	1.55	1.08	2.32	1.52	7.13	4.24	1.70	4.26	2.14
5	2.38	3.10	2.30	2.56	7.10	6.30	4.70	9.44	10.40

Kcal/gm, respectively, as indicated in Table 2-D (9).

RESULTS AND DISCUSSION

Goldfish fed 30% DPW or 30% sewage sludge diet showed growth as good or better than controls (Table 3-D). This result was not expected because of the lower nutrient value and lower caloric value in the experimental diets. After five months, fish in the control, 30% sewage sludge diet and 30% DPW diet groups yielded 417%, 475% and 627% increases in body weight, respectively. Assuming that the initial unequal weight caused no significant differences in growth rate, the data indicated no significant difference ($p = 0.05$) between the control and the 30% sewage sludge group; however, there was a significant difference ($p = 0.05$) between the control and the 30% DPW group.

The average weight gain of control catfish in all three groups was greater than those in the experimental groups (Table 4-D). Fish fed on 100% DPW diets in all three groups showed a little or no growth, and thus, were not included in the report. Growth results of control fish in all three groups were significantly higher than those fed with 30% and 70% DPW diets ($p = 0.05$). These results were contrary to those of the goldfish where the control group had the lowest growth value. Feed conversion results on Table 5-D indicate that the 2% b.w. feeding level was more efficient than the 3% b.w. and 4% b.w. feeding level (for all three types of feed). These results suggest that when fish were given a lower level of feed, they tend to use the feed more efficiently. No significant difference in feed conversion was observed between feeding level of 3% b.w. and 4% b.w. in all three types of feed ($p = 0.05$).

In evaluating the diet study, it should be noted that the relative growth increase between the control and the experimental group is more important than individual growth results. Fowler (6) grew catfish fingerlings using 25% DPW mix, from 118 gms to 431 gms in five months, a 365% weight gain, while in this study 30% DPW mix in all three levels of feeds, 2%, 3% and 4% of body weight, effected weight gains of 405%, 367% and 501%, respectively, in the same time period; gains which could be due to the fact that smaller fingerlings are expected to grow faster than larger ones. The control group in all three levels of feeds, 2%, 3% and 4% of body weight, gained 592%, 941% and 1,065%, respectively; these weight gains are comparable to those outlined by Deyoe _et al_. (4) who reported that in 4.5 months catfish grew from 14.7 gms to 138.7 gms, a gain of 943%. In the experimental diet of the goldfish, one possible explanation for the better growth is that some species tend to do better at a lower nutrient level. Deyoe _et al_. (4) also reported that catfish fingerlings receiving 25% protein diet grew better than those on a 22% protein diet. The corrected protein in control (salmon feed), 30% DPW and 30% sludge was 37.2%, 29.9% and 30.4%, respectively (calculated from data in Table 1-D).

The relatively poor growth rate in catfish fed on 30% DPW may indicate that the species' needs were not met as well as for goldfish or the catfish might be more sensitive to unknown contaminants such as heavy metals. This reasoning, coupled with the possibility that some fish may grow better with a less rich feed, may explain the better growth rate in goldfish than in catfish given the same feed. The diminishing growth rate in goldfish in the last two months, might be attributed to the genotypic factor. An examination of goldfish taken from the same pond as those used in the experiment showed the strain to be small.

In conclusion, the results from the experiment using goldfish appeared encouraging and results from the catfish experiment slightly less promising. It would seem premature to make any definitive conclusions from the presented data. Nevertheless, the concept of converting waste substances into usable materials is highly desirable. The advantages are many including a partial elimination of a waste disposal problem, a supply of usable materials at little cost and good environmental practice. Researchers pursuing the study of recycling wastes as feed supplements must be aware of the physical characteristics of the product such as offensive odors (2) and contaminants that may have toxic effects such as heavy metals (1). It is reasonable to assume that with further refinements of waste processing techniques, the potential will be great for high nutrient values in recycled wastes.

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APPENDIX E. BIOLOGICAL AVAILABILITY OF PROTEIN FROM POULTRY ANAPHAGE

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INTRODUCTION

Poultry anaphage (dried poultry waste or DPW) varies considerably in its nitrogen content (1). A considerable proportion of the nitrogen is in the form of uric acid, which makes practically no contribution of nitrogen to carcass protein when anaphage is incorporated into a hen's ration. However, about 10-12% of the anaphage contains "true protein" (4, 9 and 5). There is indirect evidence that the protein in anaphage is available to the chick (5) and hen (6). The proportion of the nitrogen and thus crude protein (N x 6.25) that is available from anaphage has not been established.

In this study, Japanese quail, which grow extremely rapidly during their first few weeks of age, were used as assay animals. Net protein values (NPV) and protein efficiency ratios (PER) were calculated for diets that contained 12.5 to 25.0% of isolated soybean protein (I.S.P.) supplemented with methionine. Anaphage was added to these diets over four levels and in a protein-free diet.

PROCEDURE

Day-old Japanese quail were reared in a battery-brooder for seven days and fed a diet that contained a protein level of 15% (Table 1-E), with the idea that protein for growth would be marginal. On day seven, the quail were individually weighed, then sorted by weight and transferred as groups of 15 of nearly equal body weight to a battery-brooder with 24 pens. Twelve treatments with two replications per treatment (Table 3-E) were assigned at random, using a table of random numbers.

The test diets outlined in Table 2-E and a practical diet (Table 1-E) were then fed for seven days. One set of diets was formulated to provide protein only from isolated soy protein, supplemented with methionine.

The other set of diets contained the same gradient amounts of isolated soy protein (I.S.P.), plus the poultry anaphage as the other source of protein. All diets were isocaloric.

The sodium, chloride, calcium and phosphorus values in the diets containing anaphage were not adjusted. The assumption was that in the short span of seven days, these elements would not have an adverse effect on the formation of carcass protein or, if they did, it would not influence the response to be other than gradient. The anaphage sample was a composite of three samples from different sources.

On day 7 of the experiment, the quail were weighed and killed with chloroform. Eight of the quail that weighed closest to the mean weight were selected from each group. They were pooled into two groups of 4.

All of the gut contents were cleaned from the intestines, and the carcasses with the intestines were oven-dried to constant weight to determine the percentage dry matter. The pooled samples were ground to a fine powder. Percentage dry matter and nitrogen (Kjeldahl) was determined on the carcasses and the diet. Crude protein (C.P.) was equal to N x 6.25. Statistical procedures were those by Snedecor and Cochran (7) and Bliss (2). Differences among values were considered significant at F-ratios of probability .05 or less.

RESULTS

The protein-free diet without and with anaphage contained 0.54 and 7.16% C.P., respectively (Table 4-E). The difference of 6.6% C.P. represented the contribution of C.P. from anaphage. Practically the same difference was found upon analyses of the other pairs of diets, and the overall average of 6.58% agreed closely with the value based upon the analysis of the anaphage for N and its contribution at 30% of the diet (Table 4-E).

Quail fed the diets with anaphage ate consistently more feed than those fed comparable levels of I.S.P. without anaphage. However, when the total feed consumed was corrected for the anaphage as 30% of the dietary weight, the actual amounts of the basal mix and thus I.S.P. consumed by the quail receiving anaphage were less than those fed the diets without anaphage (Table 5-E). Despite this, the final body weights and body weight gains (Table 5-E) were consistently greater than their counterparts receiving the comparable feed level of I.S.P.

The diets were isocaloric; therefore, the difference in feed intake could not be accounted for as an energy deficit. Presumably the low protein levels accounted for the lower feed intake (Table 5-E), with the small contribution of C.P. from the anaphage causing an improvement in feed intake.

Nitrogen intake per bird was much higher in those quail fed the anaphage. Carcass N was higher in these quail from four of the five test groups (Table 6-E). Thus, anaphage did contribute N for carcass N. There was a trend for the water:nitrogen ratios to increase slightly, yet significantly ($P \leq 0.05$), as the level of protein increased (Table 6-E). The crude protein accounted for 21.2% of the quail's body weight and treatment with graded levels of protein had no significant effect on this value. Thus, quail chicks contain more protein per unit of body weight then young chickens, which average 18% protein in their carcasses (8).

The data in Tables 5-E and 6-E were used to calculate net protein values (NPV), according to the suggestions of (3 and 8). The data were also used to calculate protein retention efficiency (PRE) using the determined value of percent carcass protein, whose mean was 21.2%. The NPV and PRE values are given in Table 7-E.

The diets with I.S.P. supplemented with methionine to improve I.S.P.'s amino acid profile yielded NPVs ranging between 46.4 and 50.7, with a mean of 48.9. Quail fed anaphage plus the I.S.P. had much lower values for NPVs ranging from 21.3 to 32.8 with a mean of 27.5. The NPVs for the anaphage + I.S.P. were based on the assumption that all N from the anaphage containing 3.50 g N/100 g (21.9% C.P.) was biologically available C.P., which it was not. In fact, nitrogen accounted for as "true protein" was about 10% of product weight. Thus, the NPVs for the diets that contained anaphage can be considered to be biased toward the low side.

The PRE values were in agreement with the NPVs for each respective treatment and were also assumed to be biased toward the low side of the diets with anaphage.

An attempt was made to assess a more meaningful contribution of the anaphage to the protein level of the diet. The method outlined by Bliss (1951) was used to do this. A plot (fig. 1-E)made between the level of I.S.P. in the diet and the resultant body weight of quail on day 7 (14 days of age) of the experiment, had less curvature to the lines than that produced on the basis of an arithmetic relationship between the two criteria.

A somewhat linear relationship existed over the range of 15.8 to 21.4% I.S.P., as log values, vs. body weight and this portion of the curve was assumed to be adequate for statistical treatment. Such an analysis revealed that the two lines have a similar slope, b = 52.53, but were at significantly different elevations. The two regression lines, based on pooled slopes, were $\hat{y} = -43.9 + 52.53\ X$ for I.S.P. alone, and $\hat{y} = 46.2 + 52.53\ X$ for I.S.P. + anaphage where X = log percent of I.S.P. level in diet and $\hat{y}$ = body weight in grams.

The diets with anaphage plus I.S.P. produced a 10.7% greater body weight than those diets that contained comparable levels of I.S.P. alone.

Body weight gain, by itself, is not necessarily indicative that carcass protein accounts for some of this gain. Specifically, an increase in carcass protein must be demonstrated with some N coming from anaphage. Table 8-E contains the data to indicate that anaphage contributed to protein deposition in quail.

First, we calculated the net amount of C.P. consumed by subtracting the small quantity of C.P. intake obtained from the protein-free diet (Table 5-E). On the average, the quail-fed diets that contained anaphage consumed 89.8% of the amount of crude protein from I.S.P. + MHA than those quail fed the diets without anaphage. The percentage values increased progressively from 86.5 to 94.2% (Table 8-E). Then we calculated the net amount of carcass protein, as compared to the protein-free diets (carcass protein of test group less carcass protein of groups fed protein-free diet). The groups fed anaphage averaged 102.4% of those not fed the anaphage. Thus, on an average of 10.2% less protein from I.S.P., the quail given anaphage had 2.4% more carcass protein, a net difference of 12.6% effectiveness from anaphage. Thus, 30% anaphage in the diet was equivalent to about 12.6% of I.S.P. + MHA for deposition of carcass protein, a value similar to the 10.7% equivalent effect determined from the body weight data in Figure1-E. The average of these two values (11.7%) could be assumed to be the best representative value to use for calculating the available C.P. from anaphage.

The data in Table 8-E are essentially the same used to calculate NPV, except that the values have been expressed in terms of C.P. instead of N. Thus, one unit of carcass protein deposited in quail required two units of protein from I.S.P. + MHA in the diet.

The quail were about 50% efficient in taking the protein from I.S.P. + MHA in the diet and depositing it as carcass protein, over the range of the assayed levels. Accordingly, to produce an 11.7% increase in carcass protein from I.S.P. + MHA, there would be required a 23.4% increase in protein level, because the value of NPV is about 50% (NPV=49.5).

Within the assay range, if one assumed that I.S.P. + MHA were fed at a 15.8% level in the diet, then a 23.4% increase in protein level would bring the level to 19.5% protein. This value, which is 3.7 percentage units higher than the 15.8% level, is what 30% anaphage was supplying in carcass N to produce its equivalent value to I.S.P. + MHA. Therefore, if 30% anaphage has available protein equivalent to 3.7% anaphage assays to be $\frac{3.7}{.30}$ = 12.3% available protein.

At the higher range of the assay values, the equivalent value was calculated to be [17.5 x .234 = 4.1; 4.1 + 17.5 = 21.6 (upper range of assay)] 4.1 percentage units or 13.7% available protein in anaphage. Thus, the assay indicated that between 12.3 to 13.7% of C.P. was available from anaphage.

Based on the "true protein" value determined by precipitation with trichloroacetic acid or amino acid analysis, essentially all of this protein would appear to be available to the bird. The "true protein" value obtained by chemical methods would appear to be a good assessment of the true protein in anaphage.

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TABLE 1-E. EXPERIMENTAL DIETS

	Ingredients as % of Diet	
Ingredient	Diet Fed From Day-Old to Day 7	Practical Diet Quail Starter MSU 71-8
Corn, #2 grd yellow	70.0	38.78
Soybean meal, 49%	9.0	42.0
Dist. dried grain w/sol, corn	4.0	4.0
Fish meal	3.0	4.0
Alfalfa meal	5.0	5.0
Wheat bran	5.21	---
Dicalcium phosphate	2.0	2.0
Choline chloride, 50%	0.3	0.3
1-Lysine	0.14	---
Salt, iodized	0.35	0.35
Mineral mix(1)	0.50	0.50
Vitamin mix	0.50	0.5
Corn oil	---	2.5
MHA	---	0.07
K_2HPO_4	---	0.5
Crude protein, %	15.2	29.0
M.E.-Kcal/kg	2.95	2.93

(1) Same vitamin and mineral levels as diets in Table 2-E, except that carrier in mixes was distilled dried corn with soluble containing 4% corn oil.

TABLE 2-E. EXPERIMENTAL DIETS, PURIFIED-TYPE

				Ingredients as % of Diet							
				No Anaphage						With Anaphage	
Protein Level	0	12	15	18	21	24	0	12	15	18	21
Cornstarch	10	10	10	10	10	10	10	10	10	10	10
Sugar	10	10	10	10	10	10	10	10	10	10	10
Corn oil	2.0	2.25	2.30	2.38	2.45	2.52	11.5	11.75	11.80	11.88	11.95
Isolated soy protein	0	13.9	17.3	20.8	24.2	27.7	0	13.9	17.3	20.8	24.2
Glucose	67.45	53.17	49.68	46.07	42.57	38.97	32.95	18.67	15.18	11.57	8.07
Poultry anaphage	0	0	0	0	0	0	30.0	30.0	30.0	30.0	30.0
MHA	0	0.13	0.17	0.20	0.23	0.26	0	0.13	0.17	0.20	0.23
Cellulose	4.0						0	0	0	0	0
Sand, washed	1.0						0	0	0	0	0
Choline chloride, 50%	0.5						0.5	0	0	0	0
Salt, iodized	0.35	Common to this set of diets					0.35	Common to this set of diets			
Dicalcium phosphate	2.5						2.5				
Limestone	0.7						0.7				
K_2HPO_4	0.5						0.5				
Vitamin mix(1)	0.5						0.5				
Mineral mix(2)	0.5						0.5				
Crude protein(3), %	0	12.1	15.1	18.1	21.1	24.1	0	12.1	15.1	18.1	21.1
M.E.-Kcal/kg	3332	3332	3330	3330	3330	3330	3334	3331	3330	3330	3330

(1) Vit. mix, supplies per 100 parts: Vit. A-1500 I.U.; Vit. D_3-1500 I.C.U.; Vit. E-1.0 I.U.; Menadione sodium bisulfite-0.27 mg; Thiamine mononitrate-0.6 mg; Riboflavin-1.0 mg; Niacin-10.0 mg; Pyridoxine-1.0 mg; Biotin-22 mcg; Folacin-0.5 mg; Cyanocobalamin-1.1 mcg; Starch as a carrier

(2) Min. mix, supplies per 100 parts: Manganese-5.5 mg; Magnesium-50.0 mg; Iron-8.0 mg; Copper-0.4 mg; Cobalt-5.0 mcg; Zinc-8.0 mg; Selenium-0.01 mg and Starch as a carrier

(3) Not including crude protein from anaphage

TABLE 3-E. EXPERIMENTAL OUTLINE

Dietary Protein Level %	Day 0-7	Day 7-14						
	15.0	0(1)	12	15	18	21	24	Practical Diet 29
Treatment None	No Anaphage	x(2)	x	x	x	x	x	x
	30% Anaphage	x	x	x	x	x	-	-

(1) Protein-free diet
(2) 2 reps per treatment at 15 quail/rep

TABLE 4-E. CRUDE PROTEIN (C.P.) DETERMINED IN ASSAY DIETS WITH PROTEIN SOURCE ONLY FROM ISOLATED SOYBEAN PROTEIN (I.S.P.), WITH OR WITHOUT POULTRY ANAPHAGE

Targeted C.P.-%	I.S.P.	I.S.P. + 30% Anaphage(1)	Δ
0	.54%	7.16%	6.6%
12	12.5	19.2	6.7
15	15.8	22.2	6.4
18	18.6	25.0	6.4
21	21.4	28.2	6.8
24	25.0	----	---
Practical Diet @ 29	28.7	----	---
	Anaphage Contribution	Mean = 6.58% C.P.	

(1) By calculation: Anaphage assayed @ 21.9%C.P. x 30% in diet= 6.57% C.P.

TABLE 5-E. INTAKE OF FEED AND CRUDE PROTEIN INTAKE FROM ISOLATED SOYBEAN PROTEIN (I.S.P.) AND THE RESULTANT BODY WEIGHTS AND GAIN OF JAPANESE QUAIL FROM DAY 7 TO 14 DAYS OF AGE DIETS WITH ANAPHAGE WERE SUPPLEMENTED AT 30 PERCENT OF DIET WEIGHT

C.P. From I.S.P. in Diet-% (Determined)	Feed Intake x 7 Da.-g/Quail			C.P. Intake From Other Than Anaphage-g/Quail		Final Body Wt. Per Quail-g$^{(1)}$		Body Wt. Gain Per Quail-g	
	No Anaph. Total	+Anaph. Total	+Anaph. Feed-Anaph.	No Anaph.	+Anaph.	No Anaph.	+Anaph.	No Anaph.	+ Anaph.
0.54 (Prot.-free)	4.6	13.9	9.7	0.025	0.053	8.24	9.55	-4.26	-2.99
12.5	19.8	25.4	17.8	2.48	2.15	14.27	15.40	1.77	2.90
15.8	23.2	29.3	20.5	3.67	3.24	16.70	18.84	4.20	6.44
18.6	28.9	37.3	26.1	5.38	4.85	20.84	22.84	8.37	10.41
21.4	29.3	39.5	27.7	6.27	5.91	23.39	26.03	10.85	13.61
25.0	29.4	--	--	7.35	--	24.00	--	11.50	--
28.7 (Practical Diet)	43.1	--	--	12.37	--	33.94	--	21.54	--

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(1) Initial mean weight on day 7 - 12.5 g (Range, 185-190 g/groups of 15)

TABLE 6-E. N INTAKE, CARCASS N, CARCASS WATER/N RATIOS, AND % C.P. OF TOTAL BODY WEIGHT OF QUAIL FED DIETS WITH THE PROTEIN SOURCE FROM ISOLATED SOYBEAN PROTEIN WITH OR WITHOUT POULTRY ANAPHAGE, OR A MIXED GROUP OF PROTEIN IN A PRACTICAL-TYPE DIET

C.P. in Diet %	N Intake per Bird-g		Carcass N-g		Carcass H_2O/N		% C.P. of Total Body Wt.	
	No Anaph.	+Anaph.	No Anaph.	+Anaph.	No. Anaph.	+Anaph.	No Anaph.	+Anaph.
0.54 (Prot.-free)	.004(1)	.157(1)	.302	.332	19.6	19.5	22.8	21.8
12.5	.397	.779	.499	.494	20.4	20.5	21.9	20.1
15.8	.600	1.040	.599	.640	20.5	20.4	22.4	21.2
18.6	.860	1.490	.698	.721	20.9	23.8	20.9	19.8
21.4	1.003	1.780	.803	.829	21.3	23.7	21.5	19.9
25.0	1.177	--	.845	--	21.3	--	22.1	--
28.7 (Practical)	1.979	--	--	--	23.8	--	19.8	--

---

(1) No. reps = 2 at 4 birds/rep; all others are 2 at 3 birds/rep. Birds selected on body weights closest to the mean weight. Each rep analyzed in duplicate

TABLE 7-E. THE NET PROTEIN VALUES AND PROTEIN RETENTION EFFICIENCY FOR EACH OF THE TREATMENTS USING QUAIL FED ISOLATED SOY PROTEIN WITH OR WITHOUT ANAPHAGE

Crude Protein - %	Net Protein Value (NPV)(1)		Prot. Retention Eff. (1)	
	No Anaphage	+Anaphage	No Anaphage	+Anaphage
0.54 (Prot.-free)	----	21.3	----	27.4
12.5	50.7	25.2	53.1	29.4
15.8	50.3	32.8	50.5	34.9
18.6	46.4	28.4	49.3	31.0
21.4	50.5	29.7	51.8	32.1
25.0	46.7	----	47.4	----
28.7(Pract.)	39.2	----	41.3	----

TABLE 8-E. CARCASS PROTEIN IN QUAIL RECEIVING DIETS CONTAINING AS THE SOLE SOURCE OF PROTEIN, SOY PROTEIN SUPPLEMENTED WITH METHIONINE, OR WITH ADDED POULTRY ANAPHAGE AT A LEVEL OF 30% OF THE DIET, BY WEIGHT

C.P. in Diet From Ingredients Other Than Anaphage - %	C.P. Intake From Ingredients Other Than Anaphage Net Above Protein-Free Diet - g/Quail			Carcass Protein, Net Change From Protein-Free Diet - g/Quail		
	No Anaphage	+Anaphage	%	No Anaphage	+Anaphage	%
0.54 (Prot.-free)	(2) (1)0.025(3)	(2) + 0.02	--	(2) (2)1.89(3)	(2) 0.19	--
12.5 (2)	(2) 2.45	(2) 2.12	86.5	(2) 1.23	(2) 1.19	96.8
15.8	(2) 3.64	(2) 3.21	88.2	(2) 1.86	(2) 2.11	113.4
18.6	(2) 5.35	(2) 4.82	90.1	(2) 2.51	(2) 2.62	104.4
21.4	(2) 6.24	(2) 5.88	94.2	(2) 3.13	(2) 3.29	105.1
25.0	(2) 7.32	--	--	(2) 3.39	--	--
28.7 (Practical)	(2) 12.34	--	--	(2) 3.39	--	--
			Mean = 89.8			Mean = 102.4

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(1) 2 Reps/treatment at 15 quail/rep.

(2) 2 Reps/treatment at 4 quail/rep.

(3) Value for quail on protein-free diet.

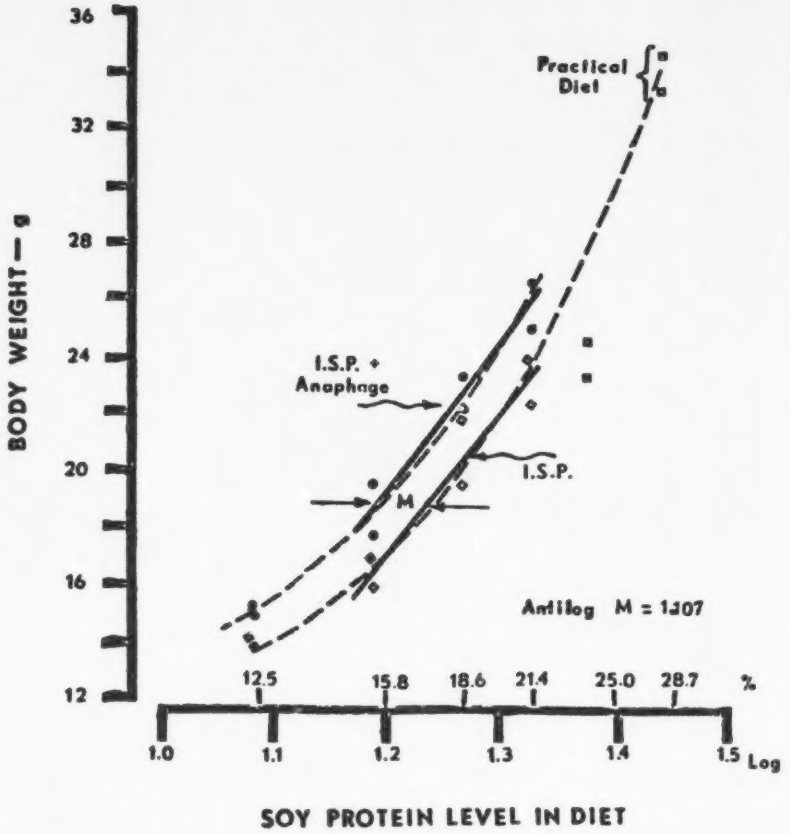

Figure 1-E. The relationship between the level of protein from isolated soybean protein (I.S.P.) alone or with anaphage at a level of 30 percent and the body weight of Japanese quail. Diets were isocaloric. The dose-response curves were considered linear over the range of 15.8 to 21.4 percent protein in order to calculate the log ratio potency (2) of the anaphage.

APPENDIX F. ACCEPTABILITY AND DIGESTIBILITY OF POULTRY AND DAIRY WASTES BY SHEEP

By

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INTRODUCTION

Several investigators have fed animal wastes (manure or feces) to animals. In general, they formed a very low proportion of the diet. No undesirable effects were reported. Refeeding some of these wastes to animals forms one way of reducing animal waste problems. One should not be too critical of attempts to re-utilize the nutrients that have passed through an animal. They contain bacteria and digestive enzymes that can be digested as well as undigested food that can be further digested. True, these wastes may not equal the original feed in nutritive value but they contain nutrients that can be used by most animals.

An examination of the chemical composition of feeds and feces shows that they are somewhat comarable. The compostion of two feeds and two feces is given in Table 1-F.

TABLE 1-F. COMPOSITION OF DRY MATTER OF 2 FEEDS COMPARED TO FECES FROM DAIRY COWS AND CAGED LAYERS

Item Compared	Protein	Fiber	E.E.	Ash	N.F.E.	TDN
Alfalfa	16	35	2.5	8.8	38	55
Dairy feces	12	40	4.4	15.0	29	--
Corn gluten feed	28	8	2.8	9.0	53	79
Poultry feces	25	10	2.0	30.0	33	--

Note the similarity in protein and fiber content. The availability and biological value of protein from feces is not adequately known but thought to be equal to that in most feeds. A calculated total digestible nutrient (TDN) value would probably be somewhat lower than the feed but this is not definitely known. A close examination of feed and feces from that same feed shows an increase in fiber, cellulose, cell walls and lignin in the feces. Yet, many rations need an increased level of fiber foroptimum animal performance. Animal wastes could furnish this fiber as well as protein and non-protein-nitrogen (NPN) for animals. The present trial was performed to test the acceptability of dried poultry and dairy waste and to determine its feeding value or digestibility using sheep.

PROCEDURE

Rations were formulated containing 31.9% dried poultry waste or 39.0% dried dairy waste and compared to one containing 11.2% soybean meal (Table 2-F). The remainder of the ration consisted of ground corn, ground corn cobs, molasses, vitamins and minerals. Each contained about 11% protein (dry basis) of which about 45% came from the feces or soybean meal.

Each ration was fed to four sheep for 14 to 21 days. During the last 7 days feces and urine were collected and digestibility and nitrogen balance calculated. The ingredients in and composition of the rations used are shown in the upper portion of Table 2-F.

RESULTS

Each ration was readily eaten by all animals. Intake of the mixed ration was 2.3 lb./cwt but was reduced to 2.0 lb./cwt for determining digestibility. Sheep accustomed to the dairy or poultry feces diet would wait for this diet when offered hay or the soybean meal diet. These waste diets were also readily consumed by dairy heifers when offered to them.

The dry matter (DM) digestibility of the waste diets was less than that of the soybean diet (58 and 62% vs. 64.6%). These diets contained more ash, more crude fiber and more lignocellulose than the soybean diet which should reduce their DM digestibility. The fiber and lignocellulose of the dairy feces ration was only slightly digestible (18-23%) while that of the poultry feces diet was highly digestible (43-50%). A TDN value for these diets containing 32 to 39% animal wastes was approximately 56%. The high ash content of poultry feces diet reduced the TDN value of this diet so that the TDN content was the same as the dairy waste diet. The actual DM digestibility of these wastes was about 54% for dairy and 73% for poultry when calculated by the different method. This confirms the idea introduced at the beginning of this article that there is a fair amount of digestible nutrients and feed value in animal feces.

The nitrogen in the dairy and poultry waste diets was only 48 and 58% digestible compared to 64.0% for the soybean meal diet. Nitrogen balance was markedly positive for all rations being slightly less for the dairy waste ration than for the other two, (1.1 vs. 1.4 g/day). The biological value or protein stored as percent of absorbed was similar for all rations (16-18%). This shows that the nitrogen in dairy and poultry feces is of good quality for growing sheep but somewhat less digestible than that of soybean meal.

SUMMARY

Dried poultry and dairy wastes as about 1/3 the total mixed ration were readily acceptable by sheep. The complete ration was about 60% digestible with a TDN value of about 56. The digestibility of the poultry feces was more than that of the dairy feces. Protein of these wastes was less digestible than that of soybean meal but had a biological value equal to that of soybean meal for growing sheep.

TABLE 2-F. INGREDIENTS, COMPOSTION AND DIGESTIBILITY OF RATIONS CONTAINING FECES OR SOYBEAN MEAL AS MAJOR PROTEIN SOURCE THAT WERE FED TO SHEEP

Item	Ration		
	Dairy (%)	Poultry (%)	Soybean meal (%)
Ingredients			
Dried feces	39.0	31.9	0
Soybean meal	2.9	0	11.2
Corn cob pellets	19.5	28.9	35.6
Corn	34.1	34.3	34.1
Molasses	2.0	2.2	2.0
Mineral-Vitamin	2.4	2.7	2.4
Corn starch	0	0	14.6
Composition			
Crude protein	11.1	11.5	11.5
Crude fiber	14.6	16.6	12.0
Ash	7.8	14.8	5.6
Lignocellulose	19.1	21.5	15.8
Ration Digestibility			
Dry matter (DM)	58.1	62.0	64.6
Protein	48.5	58.2	64.0
Crude fiber	20.7	50.6	21.3
Lignocellulose	23.0	43.4	9.5
TDN	56.0	55.9	63.4
Calculated DM digestibility of protein source	±54.0	73.0	--
Nitrogen Metabolism			
N balance (g/day)	1.1	1.4	1.4
B.V. (balance ÷ absorbed x 100)	18.0	20.0	16.0

APPENDIX G. FEEDING DEHYDRATED POULTRY WASTE TO DAIRY COWS

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INTRODUCTION

Investigators have found that several classes of livestock could derive energy and nitrogen from various animal manures (1, 2, 3 and 4). The digestive system of the ruminant can convert various non-protein-nitrogen sources into amino acids that are useful to the animal. Of the nitrogen in poultry manure 25 to 75% may be in various non-protein-nitrogen forms. This non-protein-nitrogen in poultry manure may slowly hydrolyze in the rumen and form a very good source of N for ruminants. Dehydrated cage layer feces (DPW) were fed to milking dairy cows to determine if it could serve as a nitrogen and energy source.

PROCEDURE

Cows in early to mid-lactation producing 40 to 90 lb. milk per day were divided into four treatment groups after a 25-day preliminary or standardization period. During this and the subsequential 60-day experimental period, all cows were fed corn silage (±29-30% dry matter) ad libitum and 10 lb. alfalfa haylage. Grain mixture was fed at 1 lb. per 3 lb. milk. During the 60-day experimental period, group 1 (negative control) received a grain mix containing 8.4% crude protein; group 2 (positive control) received a grain mixture containing 19.1% crude protein; group 3 received a grain mixture containing 14% protein, plus corn silage ensiled with non-protein-nitrogen sources; and, group 4 received a grain mixture containing 30% dehydrated caged layer feces (DPW) with a crude protein level of 19%. Thus, the N source for group 4 could be compared to a usual N source of soybean meal (group 2) and NPN source (group 3), as well as that of a suboptimal level (group 1). Feed refusals were determined and net intake calculated. Rations fed and amount consumed are shown in Table 1-G.

Milk was weighed daily and fat test determined at approximately biweekly intervals. There were 7 cows in groups 1, 2 and 4, and 14 cows in group 3.

RESULTS

Consumption of the grain mixture containing 30% dehydrated poultry waste (DPW) was as great as that of cows fed normal grain mixtures after the cows became accustomed to the material (Table 1-G). Two cows consistently had larger refusals than expected, but still consumed about 1 lb. grain/ 3 lb. milk. When started on the experimental trial, the seven cows on DPW were fed a concentrate mix with only 15% DPW during the first week.

After this the 30% mixture was fed at all times. A preliminary trial indicated that unadjusted cows would not consume a concentrate mixture containing 50% DPW. The highest level that would be consumed by cows gradually adjusted to DPW is not known.

On two separate days, milk samples from the 7 cows fed DPW was scored for flavor by Professor J. Jensen of the Department of Food Science and Human Nutrition. Milk from cows fed other rations was also scored.

Average scores for cows fed rations 2, 3 and 4 were 37.5, 37.0 and 37.6, respectively. Flavor of milk from DPW fed cows was normal.

Level of milk production during the 60-day experimental period was about the same for cows in groups 2, 3 and 4 (46.5 to 49.3 lb./day). Group 1 cows fed the low protein ration produced only 42.9 lb./day. The change in production from preliminary period to experimental period was about equal (-7.0 to 9.0 lb./day) for groups 2, 3 and 4 and was greater (-12.5) for cows in group 1 as shown in Table 2-G. The persistency was normal for cows fed DPW and greater than that for cows fed the low protein ration. Changes in milk fat test and body weight are also listed in Table 2-G. Values for cows fed DPW were normal.

Cows in group 4 consumed about 5.1 lb. of DPW, so, about 22% of the total N intake of these cows came from DPW. The results indicate that cows in groups 2, 3 and 4 utilized their supplimental N efficiently and similarly when compared to the responses of cows fed insufficient protein (group 1).

Dehydrated caged layer feces was successfully used to furnish a portion of the dietary protein and energy in the diet of milking cows. Thus, products similar to that used here could replace 15 to 20% of the dietary protein of ruminants.

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GLOSSARY

Ad libitum: Free choice, without restriction as to amount or time.

A-V: Animal-vegetable

Anaphage: A word coined by Dr. Don Polin of Michigan State University's Poultry Science Department, taken from the Greek words "ana" (again) and "phage")to eat), thus, "to eat again".

Bedding: Inclusive term used to identify materials used for livestock and dairy cattle, and includes straw, hay, shavings and sawdust.

°C: degrees Celcius

Dehydrating: The removal of all or most of the mositure from a substance, particularly for the purpose of preservation.

Dried poultry waste (DPW): A term applied to poultry excreta exposed to heat (artificial or mechanical).

Droppings: The excrement of birds and animals.

Excreta: Waste substances eliminated from a fowl or livestock as discharged from the bowels.

In situ: In a given or natural position; undisturbed.

Litter: Term used to identify materials used as bedding on floors of broiler or layer houses and includes shavings, sawdust, peat moss and/or hulls.

Manure: Excreta of animals (dung and urine), used to fertilize land.

Metabolizable energy (M.E.): Gross energy intake minus energy loss in excreta, thus, M.E. is energy retained by the animal, and usually expressed in terms of energy units (kilocalorie) per unit of substance fed or lost, on a dry weight basis.

Pit: Area beneath laying cages used to contain manures and excess water and may be either a shallow or deep pit.

Pit cleaner: Device used to clean out excreta from underneath cages.

Poultry anaphage (PA): A word describing a product derived from the process of dehydration of poultry excreta (not liter), exposed to at least 143°F (61.6°C) or higher temperature for at least 1 minute or longer, thus, reducing the moisture content of the product to below 15% and reducing the pathogen content to zero.

Stabl: Stabilized with an antioxidant.

Utilization: The extent to which a ration, feed or nutrient is used.

Waterers: Describes equipment used for holding drinking water for caged or floor birds.